RELIABILITY TESTING OF THE MOD III-T TWO AXIS DYNAMICALLY TUNED GYROSCOPE

FINAL TECHNICAL REPORT

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Testing program to determine the long-term performance characteristics of the Textron Defense Systems' MOD III-T Two-Axis Dynamically Tuned Gyroscope.

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FORWARD

This final report documents the results of the reliability testing of Textron Systems Division's Gyroscope Model III-T, two axis dynamically tuned rotor Gyroscope. The testing was performed under the NASA Contract NAS5-31954 for the SMEX Gyros.

This report is organized as follows:

Section 1 - Introduction and Conclusion

Section 2 - Technical section which analyzes the tuning concept for the Gyro.

Section 3 - Technical section which derives the Gyro Error Model equations.

Section 4 - Test Results of the reliability test including the Plots.

Section 5 - Appendices which include the test setup, the test procedures and the log.

SECTION 1

INTRODUCTION, CONCLUSIONS

INTRODUCTION

NASA Godard Space Flight Center under Contract NAS 5-31954 contracted Textron Systems Division (TSD) to conduct 3 year Life and Reliability Test on TSD's Model III-T dynamically tuned rotor gyroscope. This gyro was specifically designed for NASA in the early 1980s for space flight applications. The purpose of these tests was to establish that the Model III-T Gyroscope (Part Number 760900-533) would meet the performance requirements for the three year space mission, SMEX Mission. Two gyroscopes Serial Numbers 3334 and 3327 were utilized to perform the life tests. The gyros were turned on and continuously running for three years in an operational bed which was a temperature controlled oven maintained at 125˚F - 130˚F environment. The gyros were operated at their Synchronous speed, 400Hz, in a closed-loop-mode (torque-to-balance). During the first six months, each gyro was taken out of the operational bed every two weeks on to the test laboratory where it was Performance tested. The Performance Parameter Specifications, against which each gyro was tested, are listed on Page 10 of Textron Test Procedure document number 600218. The procedure is attached in Section 5 of this report. After six months, the frequency of performance testing was changed to once a month. The NASA MOD III - Gyro Life Test Plan and Procedure No. 600218 also details the required test equipment, and the gyro orientation requirements. A detailed laboratory log was maintained and records of all the events throughout the 3 year life tests were maintained e.g., power outages, equipment failures and quality assurance inspection records. Also included in Section 5 of this report is a block diagram for the Performance Test Bed drawing number 767158.

CONCLUSION

The two gyros met and in most cases far exceeded all the specification requirements for the SMEX Gyroscope as evidenced in the test results summary sheets and plots given in Section 4. These results are far superior than was anticipated especially given the fact that the test results deviations also include the additional terms which are not part of the gyro errors. For example, mount-to-mount repeatability and the test equipment errors are all lumped under total gyro performance error budget.

Utilizing the final error equation from Section 3 and the plots of test results from Section 4 of this report, one can conclude the following:

(a) The gyro run up times throughout the 3 years have been fairly steady, i.e., 10 - 11 seconds with a standard deviation of less than 1/2 second. This indicates that the gyros are fairly smooth and no deterioration of the bearings within the last 3 years of operation or otherwise the run up time would have gone up from additional friction due to the bearing wear.

(b) The plots for the motor start-up current on both gyros indicates fairly constant value over the 3 year time frame indicating that there is enough power to start the gyros and no degradation in the motor. The two spikes at 520 days on both gyros indicate test equipment read out problems rather than the deterioration, since its very systematic on both gyros and also the spikes happen only once out of 45 times.

(c) The motor run current plots indicates a slight trend of approximately .3 ma per month, however the standard deviation is very small. This probably results from increase in internal friction with time but the degradation rate indicates that the gyro would be good for at least 10 more years before the increase in friction becomes a problem rendering the gyro unusable.

(d) The motor run down time also shows that the time required for both gyros to run down is shorter. This again illustrates that the internal friction is higher.

(e) Plots for the tuned frequency indicate that initially the gyros had step changes in their tuned frequency, however the step change stabilized with time and this is probably due to the gyro weights settling initially while the epoxy was curing and towards the end the settling has been accomplished. It should be noted that the total change in tuned frequency over the three year period is approximately 2 Hz which is well within the design and performance specifications.

(f) The time constant plots on both gyros indicate that with time the gyro time constant is decreasing at a very low rate. The time constant is a function of damping. The MOD III T gyros are back filled with helium to keep the damping terms in the error equation low enough. When the gyro develops a leak, the helium is replaced by air which is much more denser than helium and hence would result in higher damping coefficient and a noisier gyro. On these two gyros, the time constant has decreased slightly over the three years, which indicates that the air is seeping in and replacing the helium and hence increased damping. This is not unusual since the gyro can never be hermetically sealed and the 3 T Gyros are designed to leak at 10^{-8} tours. With the present leak rate this gyro should be good for the next 15 years before its too noisy for leak to render it non-usable.

(g) All the remaining plots i.e., offset angles, null angles, the torquer scale factors, the g-insensitive error terms and the g-sensitive error terms versus time on these gyros indicate that there has been no degradation with time and they all meet or exceed the SMEX Mission performance requirements.

SECTION 2

ANALYSIS OF SUSPENSION SYSTEM AND THE TUNING CONCEPT

The function of the suspension system in a tuned rotor gyro is to provide translational support for the rotor in such a way that the effective torsional coupling between rotor and gyro case about any axis perpendicular to the rotor spin axis is zero. The suspension system consists of an inertia element (the gimbal) and the torsional elements (flexures). Positive spring torque between rotor and shaft due to the torsional elements when balanced by negative spring torque due to the dynamic behavior of the rotor result in a tuned gyro condition.

In this section a suspension system is analyzed in detail under the desired tuning condition. Basic assumptions are made to simplify the analysis without loss of validity or implying physical limitations. Coordinate frames are defined. Expressions relating the moments acting on the rotor as a function of case inputs are developed. Finally, the tuning conditions in terms of the external input are analyzed.

2.1 Assumptions

Assumptions made to simplify the mathematical manipulations are:

1) The rotor inertias are much greater than the gimbal inertias. The spinning rotor may then be considered to have an invarient attitude relative to the inertial space.

2) The effects of damping are negligible due to the large clearance between the rotor and the gyro case.

3) The attitude angles ϕ_x and ϕ_y (see Figure 2-2) are considered

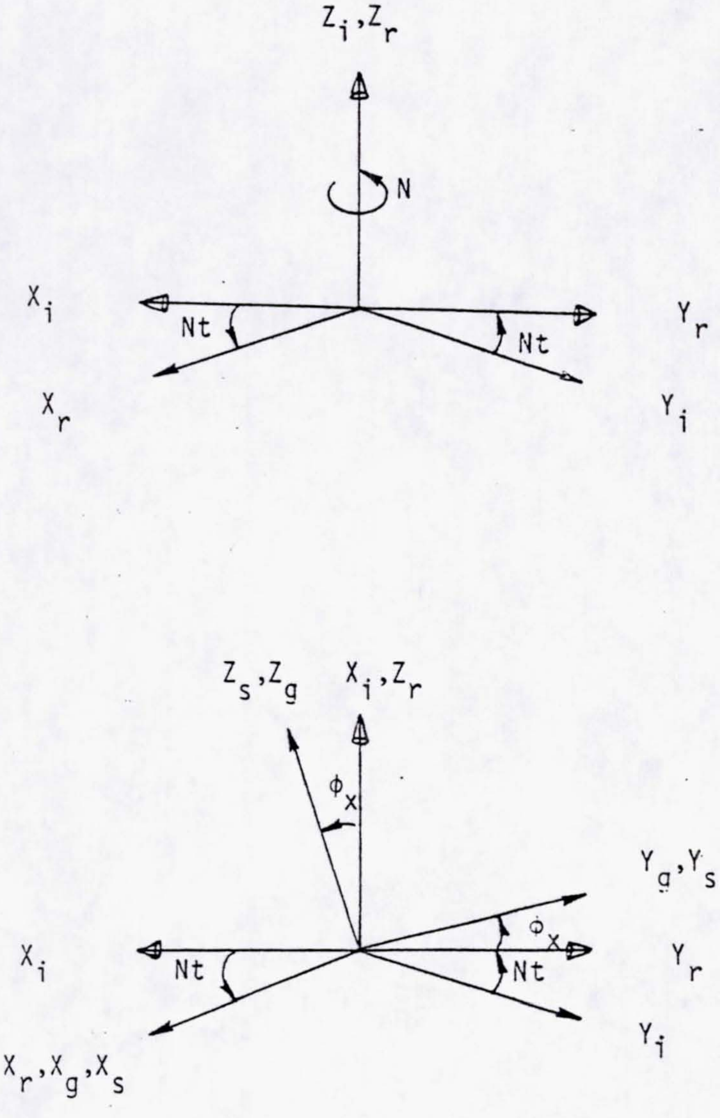


Figure 2-1 Relationships between the coordinate frames.

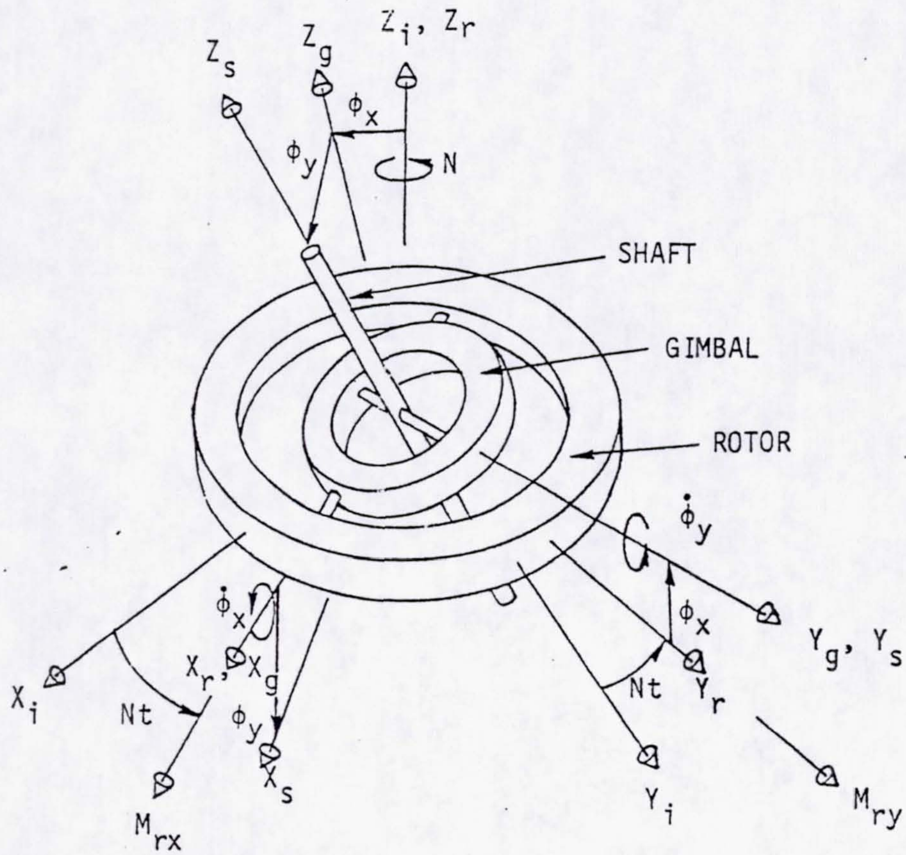


Figure 2-2 Rotor, gimbal, and shaft deflections.

small, hence small angle approximations apply (i.e., $\cos \phi_x = 1$; $\sin \phi_x = \theta$).

2.2 Coordinate Frames

The coordinate frames needed to generate relationships relative to each other are:

1) X_i, Y_i, Z_i	Coordinate set is fixed relative to inertial space. Rotor spins about Z_i axis with angular velocity N.
2) X_r, Y_r, Z_r	Coordinate set is fixed in the rotor (r-set)
3) X_s, Y_s, Z_s	Coordinate set is fixed in the shaft. The instantaneous attitude of the gyro shaft relative to the r-set is specified by angles ϕ_x and ϕ_y (see Figure 2-2). ϕ_x and ϕ_y are considered to have been generated by the angular velocity of the shaft relative to the r-set ($\dot{\phi}_x$ and $\dot{\phi}_y$).
4) Z_g, Y_g, Z_g	Coordinate set is fixed in the gimbal. Figures 2.1 and 2.2 show the relationships between various coordinate frames.

2.3 Angular Velocities

From Figure 2-1, the angular velocity of the rotor relative to the inertial space resolved along the rotor axes is:

$$\omega_{ir}^{r} = \begin{bmatrix} \omega_{ir(x)} \\ \omega_{ir(y)} \\ \omega_{ir(z)} \end{bmatrix}^{r} = \begin{bmatrix} 0 \\ 0 \\ N \end{bmatrix}$$

where superscript refers to the frame along which the vector is coordinatized.

The angular velocity of the gimbal relative to the rotor axis and resolved along the gimbal axis is;

$$\omega_{rg}^{g} = \begin{bmatrix} \omega_{rg(x)} \\ \omega_{rg(y)} \\ \omega_{rg(z)} \end{bmatrix}^{g} = \begin{bmatrix} \dot{\phi}_x \\ 0 \\ 0 \end{bmatrix}$$

The matrix for transforming velocities from the rotor coordinates to the gimbal coordinate after applying small angle approximations, is:

$$C_r^g = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & \phi_x \\ 0 & -\phi_x & 1 \end{bmatrix} \qquad (2\text{-}1)$$

Angular velocity of the gimbal relative to the inertial space, coordinatized in the gimbal frame, can be obtained by summing the angular velocities as shown by Equation (2-2a). First term on the right hand side of Equation (2-2a) is the angular velocity of rotor relative to the inertial space transformed to the gimbal frame by matrix C_r^g and the second term is the angular velocity of the gimbal relative to the rotor coordinatized in the gimbal frame.

$$\omega_{ig}^{g} = C_r^g \omega_{ir}^{g} + \omega_{rg}^{g} \tag{2-2a}$$

$$\omega_{ig}^{g} = \begin{bmatrix} \omega_{ig(x)} \\ \omega_{ig(y)} \\ \omega_{ig(z)} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & \phi_x \\ 0 & -\phi_x & 0 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ N \end{bmatrix} + \begin{bmatrix} \dot{\phi}_x \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \dot{\phi}_x \\ \phi_x N \\ N \end{bmatrix} \tag{2-2b}$$

2.4 Moments Acting on the Rotor

Figure 2-2 shows the rotor, gimbal and the shaft positions resulting from a deflection of the outer torsional bar through an angle ϕ_x generated by the angular velocity $\dot{\phi}_x$.

Referring to Figure 2-2, moments acting on the rotor coordinatized along the rotor frame, M_{rx}^{r}, is due to the deflection of the outer torsional bar through an angle ϕ_x.

$$M_{rx}^{r} = K_x \phi_x \tag{2-3}$$

Applying Euler's equation of motion to the gimbal about its Y-axis yields;

$$M_{gy} = B_g \dot{\omega}_{ig(y)}^{g} - (C_g - A_g)\omega_{ig(z)}^{g}\omega_{ig(x)}^{g} \tag{2-4}$$

where A_g, B_g and C_g are moment of inertias of the gimbal for X_g, Y_g and Z_g axes, respectively.

Summing the moments acting on the gimbal about the Y_g-axis, and noting that the Y_g axis coincides with the inner torsional element, results in;

$$M_{gy} = K_y \phi_y - M_{ry}^{r} \tag{2-5}$$

where ϕ_y is the angular displacement of the inner torsional element generated by angular velocity $\dot{\phi}_y$ that the shaft has relative to the gimbal set. Carrying out the substitution of Equation (2-5) into (2-4) and solving for M_{ry}, results in:

$$M_{ry}^{r} = -(A_g + B_g - C_g)\omega_{ig(x)}^{g}\omega_{ig(z)}^{g} + K_y\phi_y \tag{2-6}$$

Substituting ω_{ig}^{g} from Equation (2-2b) into Equation (2-6) gives the moment acting on the rotor about its Y_r axis:

$$M_{ry}^{r} = -(A_g + B_g - C_g)\dot{\phi}_x N + K_y\phi_y \tag{2-7}$$

Assuming that the instantaneous angular displacement of the gyro case relative to the inertial space about the X_i-axis is equal to θ_x then:

$$\begin{aligned} \phi_x\big|_c &= \theta_x \cos Nt \\ \phi_y\big|_c &= -\theta_x \sin Nt \\ \dot{\phi}_x\big|_c &= \dot{\theta}_x \cos Nt - \theta_x N \sin Nt \\ \dot{\phi}_y\big|_c &= -N\theta_x \cos Nt - \dot{\theta}_x \sin Nt \end{aligned} \tag{2-8}$$

Substitution of Equation (2-8) and (2-7) yields rotor moments along the X_r and Y_r axes in terms of external case inputs (θ_x).

$$\begin{aligned} M_{rx}^{r} &= K_x\theta_x \cos Nt \\ M_{ry}^{r} &= \left[(A_g + B_g - C_g)N^2 - K_y\right]\theta_x \sin Nt - (A_g + B_g - C_g)N\dot{\theta}_x \cos Nt \end{aligned} \tag{2-9}$$

From Figure 2-3, the matrix, C_r^c, for transforming a vector from rotor to case axes is;

$$C_r^c = \begin{bmatrix} \cos Nt & -\sin Nt \\ \sin Nt & \cos Nt \end{bmatrix} \tag{2-10}$$

Transforming rotor moments, M_{rx}^r and M_{ry}^r to case coordinate frame gives:

$$\begin{bmatrix} M_{rx}^c \\ M_{ry}^c \end{bmatrix} = C_r^c \begin{bmatrix} M_{rx}^r \\ M_{ry}^r \end{bmatrix} = \begin{bmatrix} \cos Nt & -\sin Nt \\ \sin Nt & \cos Nt \end{bmatrix} \begin{bmatrix} M_{rx} \\ M_{ry} \end{bmatrix}^r = \begin{matrix} M_{rx}^r \cos Nt - M_{ry}^r \sin Nt \\ M_{rx}^r \sin Nt + M_{ry}^r \cos Nt \end{matrix} \tag{2-11}$$

Substituting rotor moments (M_{rx}^r and M_{ry}^r) from Equation (2-9) into (2-11) gives:

$$\begin{aligned} M_{rx}^c &= K_x \theta_x \cos^2 Nt - \left[(A_g + B_g - C_g)N^2 - K_y)\right] \theta_x \sin^2 Nt \\ &\quad + \left[A_g + B_g - C_g\right] \dot{\theta}_x N \cos Nt \sin Nt \\ M_{ry}^c &= K_x \theta_x \sin Nt \cos Nt + \left[(A_g + B_g - C_g)N^2 - K_y\right] \theta_x \sin Nt \cos Nt \\ &\quad - \left[A_g + B_g - C_g\right] \dot{\theta}_x N \cos^2 Nt \end{aligned} \tag{2-12}$$

Applying the following trignometric identities:

$$\cos^2 Nt = 1/2 \left[1 + \cos 2Nt\right]$$

$$\sin^2 Nt = 1/2 \left[1 - \cos 2Nt\right]$$

$$\sin Nt \cos Nt = 1/2 \sin 2Nt$$

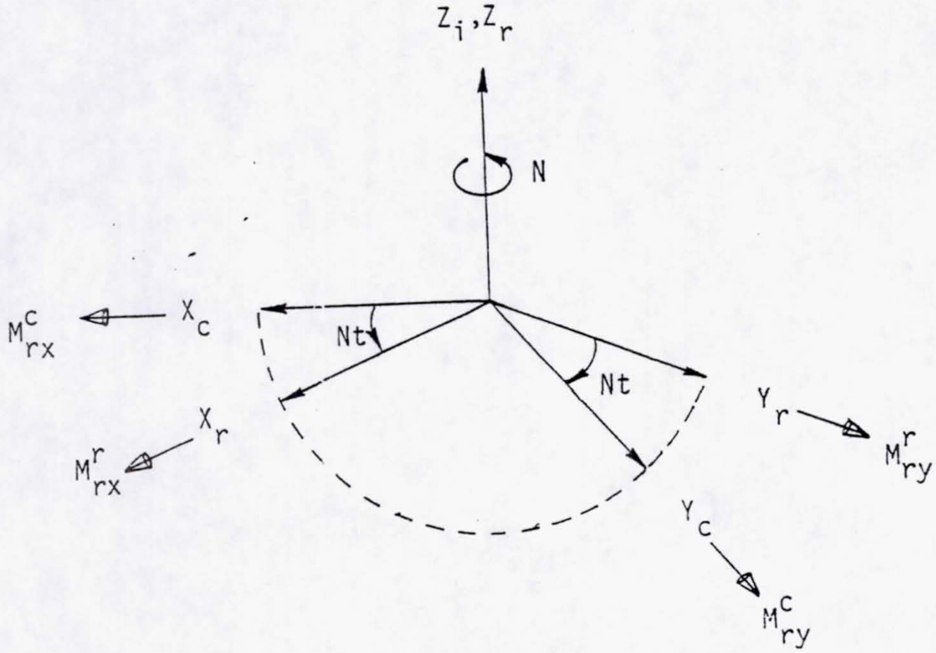


Figure 2-3 Relationship between the case (c) and the rotor (r) coordinate frames.

Equation (2-12) simplifies to the following expressions:

$$M^c_{rx} = 1/2\left[(K_x + K_y) - (A_g + B_g - C_g)N^2\right]\theta_x$$

$$+ 1/2\left[(K_x - K_y) + (A_g + B_g - C_g)N^2\right]\theta_x \cos 2Nt$$

$$+ 1/2\left[A_g + B_g - C_g\right]\dot{\theta}_x N \sin 2Nt$$

$$M^c_{ry} = 1/2\left[(K_x - K_y) + (A_g + B_g - C_g)N^2\right]\theta_x \sin 2Nt$$

$$- 1/2\left[A_g + B_g - C_g\right]\dot{\theta}_x N\left[1 + \cos 2Nt\right] \qquad (2\text{-}13)$$

M^c_{rx} and M^c_{ry} are the moments exerted on the gyro rotor (X_r and Y_r axes) transformed to the case coordinate frame. These rotor moments can now be analyzed in terms of the external case inputs.

The following comments can now be made about the results of Equation (2-13);

1) Moments on the rotor have two components; time varying and time invarient. The time varying component, when averaged over a complete cycle ($2\pi n$), does not exert any torques on the rotor so long as the input frequency is not at twice the spin speed frequency.

2) Constant moments on the rotor will result when the input is of the form $\theta_x = \theta_{x_o}$ = constant or θ_x is at a frequency which is equal to twice the spin speed frequency:

$$\theta_x = \theta_{x_o} \sin 2Nt$$

$$\theta_x = \theta_{x_o} \cos 2Nt$$

2.5 Tuning

Tuning as defined previously is balancing the positive spring torque between the rotor and shaft due to torsional elements (K_x and K_y terms of Equation (2-13)) with the negative spring torque resulting from the rotor dynamics (A_g, B_g and C_g terms). Two cases of inputs are analyzed.

Consider first the case of a constant angular input to the gyro case. Assume an input $\theta_x = \theta_{x_o}$ = constant; Equation (2-13) reduces to;

$$M_{rx}^{c} = \frac{\theta_{x_o}}{2}\left[(K_x + K_y) - (A_g + B_g - C_g)N^2\right]$$

$$M_{ry}^{c} = 0$$

In order to have no moments on the rotor along the gyro case frame, $(K_x + K_y)$ must equal $(A_g + B_g - C_g)N^2$, i.e., tuning condition can be accomplished by adjusting gimbal inertias (A_g, B_g and C_g) or by varying the spin speed (N). For a constant spin speed, N_o, tuning is achieved by adjusting the gimbal inertia as follows:

$$N_o = \sqrt{\frac{K_x + K_y}{A_g + B_g - C_g}}$$

Note: In practice most gyros are operated at a fixed spin speed determined by the frequency of the motor supply voltage and it is common to achieve tuning by adjustment of the gimbal inertias. However, some manufacturers prefer constant gimbal inertias and achieve tuning by adjusting the spin speed or spring restraints as follows:

$$(A_g + B_g - C_g) = \frac{K_x + K_y}{N^2}$$

Either method will produce the desired results.

Consider next the effects of angular input to the gyro case at a frequency equal to twice the spin frequency

a) If $\theta_x = \theta_{x_o} \sin 2Nt$, Equation (2-13) reduces to;

$$M^c_{rx} = 0$$

$$M^c_{ry} = -1/4\left[(K_y - K_x) + (A_g + B_g - C_g)N^2\right]\theta_{x_o}$$

b) If $\theta_x = \theta_{x_o} \cos 2Nt$, then;

$$M^c_{rx} = -1/4\left[(K_y - K_x) + (A_g + B_g - C_g)N^2\right]\theta_{x_o}$$

$$M^c_{ry} = 0$$

Note: In the above equations the sinusoidal terms are deleted since the average torque resulting from them are zero.

In both cases either M_{rx} or M_{ry} is equal to:

$$-1/4\left[(K_y - K_x) + (A_g + B_g - C_g)N^2\right]\theta_{x_o} \qquad (2\text{-}14)$$

Now, assuming the gyro is spinning at a tuned speed, N_o $\left(N_o = \sqrt{\dfrac{K_x + K_y}{A_g + B_g - C_g}}\right)$ and the torsional bar stiffness, K_x and K_y are equal, then replacing K_y and N in Equation (2-14) with the above assumptions yields the following:

$$M_{rx} \text{ or } M_{ry} = -K_x/2\left[\theta_{x_o}\right] \qquad (2\text{-}15)$$

Equation (2-15) illustrates that, even though the gyro was tuned for zero error with a constant input, it will have a net error when the gyro is subjected to angular inputs at a frequency of twice the wheel speed.

In Reference 5 and 6, R. Craig has noted that in order to eliminate error torques on the rotor, due to 2N angular input frequency, at least three gimbal rings are needed in the suspension system. In a multi-gimbal design each gimbal produces an error moment, but the angular spacing of the gimbal (about the rotor spin axis), and the inertias of the individual gimbals are selected and adjusted so that the resultant of all the moments produced by the individual gimbals is equal to zero.

SECTION 3

TWO-DEGREE-OF-FREEDOM TUNED ROTOR GYRO MODEL EQUATION

In Section 2, moments acting on an ideal gyro rotor (neglecting error torques) relative to the case fixed coordinate frame were determined. In this section, however, moments supplied by the gyro torquers for the purpose of maintaining the rotor spin axis inertially stable, are determined relative to the Attitude Reference Unit (ARU) frame. By obtaining torquer moments relative to the ARU frame, effects of torquer and the case misalignments can be included in the gyro model. Also torquer moment outputs for three nominally orthogonal gyros (X, Y, Z) can be obtained.

Analysis starts with simplifying assumptions. Next, coordinate frames are defined. This is followed by calculation of angular velocities and finally, expressions relating moments supplied to the rotor by the gyro torquers are developed.

3.1 Assumptions

The following assumptions are made during the derivation of the model equation without loss of validity or implying physical limitations:

1) The rotor inertias are much greater than the gimbal inertias.

2) The gyro sensitive element rotates about the axis of symmetry and has an angular velocity relative to the gimbal set of $\dot{\alpha} = (N - \dot{\alpha}_t)$ where N is the shaft rotation and $\dot{\alpha}_t$ is the motor dynamic term.

3) The center of mass of the gimbals and the rotor coincide.

4) At first the rotor is assumed to be a free body and later on this assumption is modified to include error torques due to an imperfect suspension system, damping and 2N angular input frequency.

5) The attitude angles ξ_x, ξ_y, θ_x and θ_y shown in Figures 3-1 and 3-2 are considered small, therefore small angle approximation apply ($\cos\theta = 1$, $\sin\theta = \theta$).

3.2 Coordinate Frames

Five coordinate sets all having a common origin are used in the derivation. The Attitude Reference Unit (ARU) frame is included so that the final model equation would have moments for the X, Y and Z gyros (3 gyro package). Figures 3-1, 3-2 and 3-3 show relationship between various coordinate frames. The coordinate frames are as follows:

1) X_i, Y_i and Z_i is fixed relative to inertial space.

2) X_a, Y_a and Z_a coordinate set is the main reference frame fixed to the Attitude Reference Unit (ARU). The inertially referenced angular velocity of the ARU resolved along X_a, Y_a and Z_a axes is $\dot{\Phi}$.

3) X_c, Y_c and Z_c coordinate set is attached to the Z gyro case such that the shaft spin axis coincides with the Z_c axis. The attitude of the c-set relative to ARU set is defined by the attitude angles ξ_x and ξ_y and the angular velocity of the ARU frame resolved along the case axes (ω_{ia}^{c}) is $\dot{\Phi}'$.

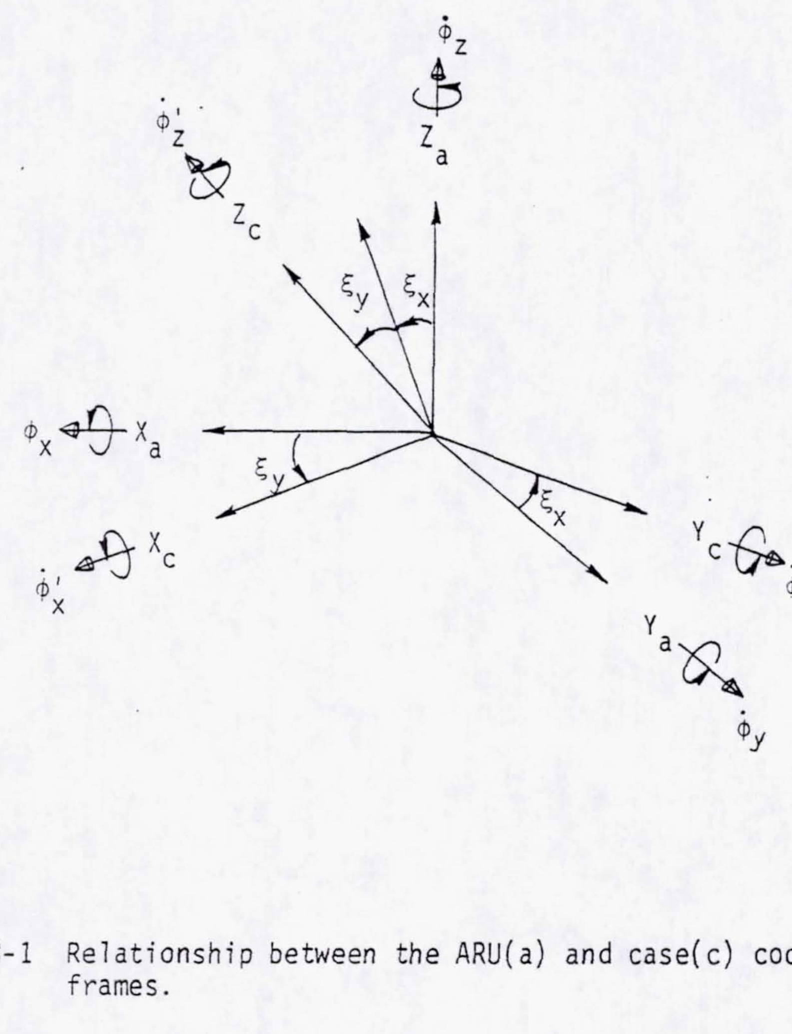


Figure 3-1 Relationship between the ARU(a) and case(c) coordinate frames.

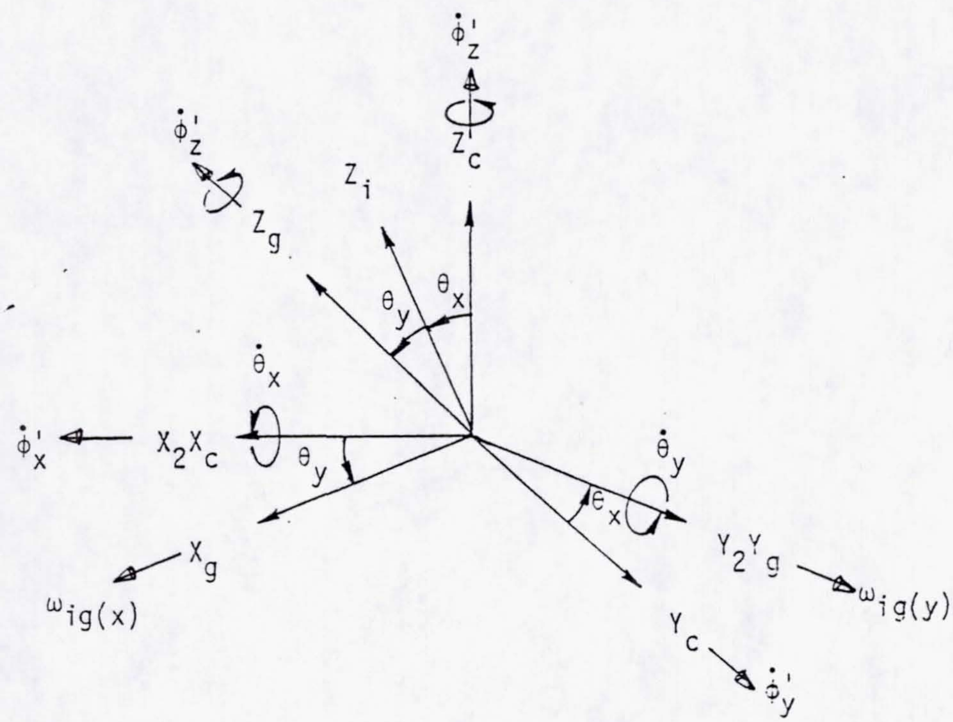


Figure 3-2 Relationship between the case(c) and gimbal(g) coordinate frames.

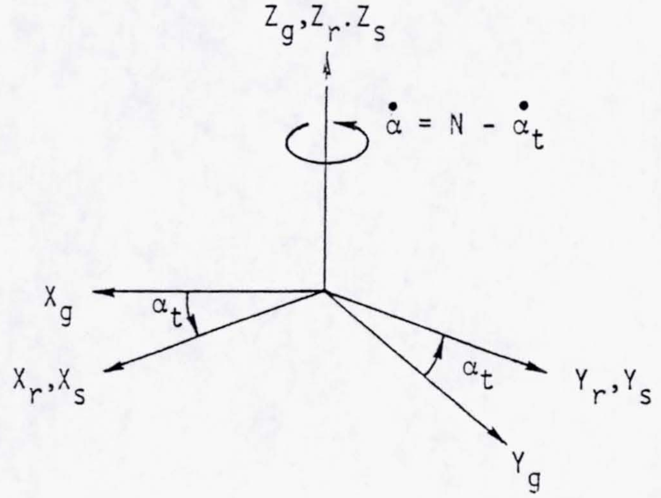


Figure 3-3. Relationship between the gimbal (g), rotor (r), and the sensitive element (s) coordinate frames.

4) X_g, Y_g and Z_g coordinate set is attached to the inner gimbal with Z_g axis coinciding with the instantaneous spin axis of the rotor. The attitude of the gimbal frame (g-frame) relative to the case frame (c-set) is given by the attitude angles θ_x and θ_y.

5) X_s, Y_s and Z_s is the sensitive element (gyro rotor and gimbal) coordinate set. The angular velocity of the sensitive element relative to the gimbal set is $\dot{\alpha} = N - \dot{\alpha}_t$ (see Figure 3-3).

3.3 Angular Velocities

From Figure 3-1, the angular velocity of the ARU with respect to inertial space resolved along the ARU frame is;

$$\omega_{ia}^{a} = \begin{bmatrix} \dot{\phi}_x \\ \dot{\phi}_y \\ \dot{\phi}_z \end{bmatrix}$$

Transforming ω_{ia}^{a} to the case reference frame yields;

$$\dot{\phi}' = \omega_{ia}^{c} = C_a^c \omega_{ia}^{a} \qquad (3\text{-}1)$$

where C_a^c is the transformation matrix obtained from Figure 2-1.

$$C_a^c = \begin{bmatrix} 1 & 0 & -\xi_y \\ 0 & 1 & \xi_x \\ \xi_y & -\xi_x & 1 \end{bmatrix} \qquad (3\text{-}2)$$

Substituting Equation (3-2) into (3-1) yields the angular velocity of the ARU frame relative to inertial space resolved along the case coordinate frame:

$$\omega_{ia}^{c} = \begin{vmatrix} \dot{\phi}'_x \\ \dot{\phi}'_y \\ \dot{\phi}'_z \end{vmatrix} = \begin{vmatrix} 1 & 0 & -\xi_y \\ 0 & 1 & \xi_x \\ \xi_y & -\xi_x & 1 \end{vmatrix} \begin{vmatrix} \dot{\phi}_x \\ \dot{\phi}_y \\ \dot{\phi}_z \end{vmatrix} = \begin{vmatrix} (\dot{\phi}_x - \xi_y \dot{\phi}_z) \\ (\dot{\phi}_y + \xi_x \dot{\phi}_z) \\ (\dot{\phi}_z + \xi_y \dot{\phi}_x - \xi_x \dot{\phi}_y) \end{vmatrix} \tag{3-3}$$

Also, from Figures (3-1 and (3-2);

$$\omega_{ia}^{c} = \omega_{ic}^{c} = \begin{vmatrix} \dot{\phi}'_x \\ \dot{\phi}'_y \\ \dot{\phi}'_z \end{vmatrix} \tag{3-4}$$

Assuming that the attitude angles θ_x and θ_y are a result of angular velocities $\dot{\theta}_x$ and $\dot{\theta}_y$ of the gimbal relative to the case, then the angular velocity of the gimbal with respect to the case, coordinatized in the gimbal frame is:

$$\omega_{cg}^{g} = \begin{vmatrix} \dot{\theta}_x \\ \dot{\theta}_y \\ 0 \end{vmatrix} \tag{3-5}$$

By definition, the angular velocity of the gimbal frame relative to inertial space and referenced along the gimbal axes (ω_{ig}^{g}) is the sum of the following angular velocities:

$$\omega_{ig}^{g} = C_c^g \omega_{ic}^{c} + \omega_{cg}^{g} \tag{3-6}$$

From Figure 3-2 the transformation matrix C_c^g is;

$$C_c^g = \begin{bmatrix} 1 & 0 & -\theta_y \\ 0 & 1 & \theta_x \\ \theta_y & -\theta_x & 1 \end{bmatrix} \tag{3-7}$$

Substituting Equations (3-4), (3-5) and (3-7) into Equation (3-6) yield angular velocity of the gimbal relative to the inertial frame along the gimbal axes:

$$\omega_{ig}^g = \begin{bmatrix} \omega_{ig(x)} \\ \omega_{ig(y)} \\ \omega_{ig(z)} \end{bmatrix} = \begin{bmatrix} \dot{\phi}'_x + \dot{\theta}_x - \theta_y\dot{\phi}'_z \\ \dot{\phi}'_y + \dot{\theta}_y + \theta_x\dot{\phi}'_z \\ \dot{\phi}'_z + \theta_y\dot{\phi}'_x + \theta_x\dot{\phi}'_y \end{bmatrix} \tag{3-8}$$

From Figure (3-3), the angular velocity of the gyro sensitive element with respect to the gimbal set is;

$$\omega_{gs}^s = \begin{bmatrix} 0 \\ 0 \\ N-\dot{\alpha}_t \end{bmatrix}$$

then, $$\omega_{is}^g = C_s^g\omega_{gs}^s + \omega_{ig}^g$$

and $$C_s^g = \begin{bmatrix} \cos\alpha_t & \sin\alpha_t & 0 \\ -\sin\alpha_t & \cos\alpha_t & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Substituting Equation (3-8), the angular velocity and the angular acceleration of the sensitive element relative to the inertial space coordinatized in the gimbal frame is,

$$\omega_{is}^{g} = \begin{bmatrix} 0 \\ 0 \\ N-\alpha_t \end{bmatrix} + \begin{bmatrix} \omega_{ig(x)} \\ \omega_{ig(y)} \\ \omega_{ig(z)} \end{bmatrix} \tag{3-9a}$$

$$\dot{\omega}_{is}^{g} = \begin{vmatrix} \dot{\omega}_{ig(x)} \\ \dot{\omega}_{ig(y)} \\ \dot{\omega}_{ig(z)} - \ddot{\alpha}_t \end{vmatrix} \tag{3-9b}$$

3.4 Moments

The basic equation used in the derivation of the gyro model is Newton's law of rotational body:

$$M = \frac{d}{dt}\left|H\right|^{i} \quad \text{(superscript i denotes coordinatized in the } i^{th} \text{ frame)}$$

For a gyroscope, the angular momentum vector of interest is the sensitive element vector which consists of the rotor and the gimbal

$$M_s = \frac{d}{dt}\left|H_s\right|^{i} \tag{3-10}$$

Applying the Coriolis Theorem to Equation (3-10) and coordinatizing the moments along the gimbal coordinate axes results in;

$$M_s^g = \frac{d}{dt}\left|H_s\right|^{g} + \omega_{ig}^{g} \times H_s^g \tag{3-11}$$

where $H_s^g = \left|I_r + I_g\right| \omega_{is}^{g}$.

Recalling assumption 1; $I_r >> I_g$, then,

$$H_s^g = I_r \omega_{is}^g$$

and

$$\frac{d}{dt}\left[H_s\right] = I_r \dot{\omega}_{is}^g$$

Substituting Equations (3-8) and (3-9) into (3-11) and letting $I_{rx} = I_{ry} = A$, $I_{rz} = C$, yields;

$$\begin{bmatrix} M_{sx}^g \\ M_{sy}^g \\ M_{sy}^z \end{bmatrix} = \begin{bmatrix} A\dot{\omega}_{ig(x)} \\ A\dot{\omega}_{ig(y)} \\ C\dot{\omega}_{ig(z)} - C\ddot{\alpha}_t \end{bmatrix} + \left[\hat{i}(\omega_{ig(x)}) + \hat{j}(\omega_{ig(y)}) + \hat{k}(\omega_{ig(z)})\right]$$

$$\times \left[\hat{i}(A\omega_{ig(x)}) + \hat{j}(A\omega_{ig(y)}) + \hat{k}(C\omega_{ig(z)} + N-\alpha)\right] \qquad (3\text{-}12a)$$

Simplifying Equation (3-12) yields;

$$M_{sx}^g = A\dot{\omega}_{ig(x)} + (C-A)\omega_{ig(y)}\omega_{ig(z)} + CN\omega_{ig(y)} - C\ddot{\alpha}_t\omega_{ig(y)}$$

$$M_{sy}^g = A\dot{\omega}_{ig(y)} - (C-A)\omega_{ig(x)}\omega_{ig(z)} - CN\omega_{ig(x)} + C\ddot{\alpha}_t\omega_{ig(x)} \qquad (3\text{-}12b)$$

$$M_{sz}^g = C(\dot{\omega}_{IAz} - \ddot{\alpha}_t)$$

M_s^g are the moments acting on the gyro sensitive element referenced along the gimbal coordinate set. These moments are actually acting on the rotor (i.e., applying assumption 1; $I_r >> I_g$ hence $M_s^g = M_r^g$). With the gyro in tuned condition; and rotor, gimbal and sensitive element z-axes coincident (see Figure 3-3), the drive shaft cannot exert any torques

on the rotor perpendicular to the shaft (i.e., M^g_{sx} and M^g_{sy}). Consequently, any moments acting on the rotor perpendicular to the shaft must be provided by the torquers which are case-mounted. Transforming rotor moments (M^g_{sx} and M^g_{sy}) to the case coordinate set using the following;

$$M^c_s = C^c_g M^g_s$$

where C^c_g is the transform of matrix C^g_c defined by Equation (3-7). Rotor moments coordinatized along the case coordinate frame are therefore:

$$\begin{vmatrix} M^c_{sx} \\ M^c_{sy} \\ M^c_{sz} \end{vmatrix} = \begin{vmatrix} 1 & 0 & \theta_y \\ 0 & 1 & -\theta_x \\ -\theta_y & \theta_x & 1 \end{vmatrix} \begin{vmatrix} M_{sx} \\ M_{sy} \\ M_{sz} \end{vmatrix} = \begin{vmatrix} M_{sx} + \theta_y M_{sz} \\ M_{sy} - \theta_x M_{sz} \\ M_{sz} - \theta_y M_{sx} + \theta_x M_{sy} \end{vmatrix} \quad (3\text{-}13)$$

M^c_{sx} and M^c_{sy} are the moments acting on the gyro sensitive element or the rotor (because of assumption 1) supplied by the X and Y torquers and not including the error torques. In practical gyroscopes error torques (M_{er}) do exist and the torquers must provide moments to overcome these error torques. (The error torques include damping, imperfect suspension system, and 2N angular input frequency rectification errors.) Therefore, net torque supplied by the gyro torquers are:

$$\begin{aligned} M^c_{tx} &= M^c_{sx} + M^c_{erx} \\ M^c_{ty} &= M^c_{sy} + M^c_{ery} \end{aligned} \quad (3\text{-}14)$$

where M^c_t are the net moments supplied by the X and Y torquers.

M_{er}^{c} are given by the following: (shown by Craig Ref. 6)

$$M_{erx}^{c} = \frac{H\left[N_o - (N + \dot{\phi}_z - \dot{\alpha}_t)\right]}{F_m}\theta_x + \frac{H}{\tau}\theta_y + D_r\dot{\theta}_x \pm HR_\theta\Phi_{2N}$$

$$M_{ery}^{c} = \frac{H\left[N_o - (N + \dot{\phi}_z - \dot{\alpha}_t)\right]}{F_m}\theta_y - \frac{H}{\tau}\theta_x + D_r\dot{\theta}_y \pm HR_\theta\Phi_{2N}$$

where $\frac{H\left[N_o - (N + \dot{\phi}_z - \alpha_t)\right]}{F_m}\theta_y$ is the mistuning error torque term for the Y-axis

$-\frac{H\theta_x}{\tau}$ is the gyro internal damping torque for the Y-axis (quadrature spring moment)

$+ D_r\theta_y$ is the Y-axis external damping error torque between the gyro and case

$\pm HR_\theta\Phi_{2N}$ is the error moments due to 2N frequency rectification (occurs only when the input is at 2N frequency)

Equation (3-14) give the moments supplied by the torquers relative to the case frame (when torquer axes coincide with the case axes). The effective torquer axes are misaligned by angles ξ_{tx} and ξ_{ty} relative to the reference ARU frame as shown in Figure 3-4 (ξ_{tx} and ξ_{ty} are small angles.)

Therefore, moments exerted on the rotor by the effective torquer are:

$$\begin{aligned} M_x &= M_{tx}^{c} + \xi_{ty}M_{ty}^{c} \\ M_y &= M_{ty}^{c} - \xi_{tx}M_{tx}^{c} \end{aligned} \tag{3-15}$$

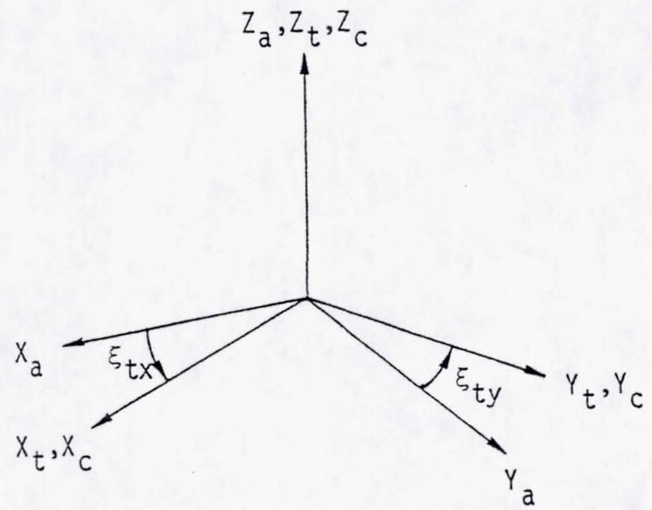


Figure 3-4. Relationship between the torquer (t), ARU (a), and the case (c) coordinate frames.

Substituting Equation (3-14) into Equation (3-15) (for M_t^c) and then substituting Equation (3-13) into the result yields;

$$M_x = M_{sx}^g + \xi_y M_{sz}^g + M_{erx} + \xi_{xy} M_{sy}^g$$
$$\qquad (3\text{-}16)$$
$$M_y = M_{sy}^g - \xi_x M_{sz}^g + M_{ery} - \xi_{xy} M_{sx}^g$$

Substituting Equation (3-12)(for M_s^g) into Equation (3-16) and then substituting for ω_{ig}^g into that result (using Equations (3-3) and (3-8)) yields the effective torquers moments in terms of the following:

a. input angular velocity $\dot{\phi}$ (ARU reference frame)

b. input angular acceleration, $\ddot{\phi}$

c. *pick-off displacement angles*, θ^z

d. pick-off angular velocity, $\dot{\theta}^z$

e. pickoff angular acceleration, $\ddot{\theta}^z$

f. misalignment angles, ξ_x and ξ_y

where the superscript specifies the gyro which does the measuring.

$$\begin{aligned} M_x^z = \; & A(\ddot{\phi}_x + \ddot{\theta}_x^z - \theta_y^z \ddot{\phi}_z - \dot{\theta}_y^z \dot{\phi}_z) && \text{(Inertia term)} \\ & + H(\dot{\phi}_y + \dot{\theta}_y^z + \theta_x^z \dot{\phi}_z) && \text{(Fundamental term)} \\ & + (C-A)(\dot{\phi}_y + \dot{\theta}_y^z + \theta_x^z \dot{\phi}_z)(\dot{\phi}_z + \theta_y^z \dot{\phi}_x - \theta_x^z \dot{\phi}_y) && \text{(Anisoinertia term)} \\ & - C\dot{\alpha}_t (\dot{\phi}_y + \dot{\theta}_y^z + \theta_x^z \dot{\phi}_z) && \text{(Motor dynamics term)} \\ & + C(\ddot{\phi}_t - \ddot{\alpha}_t^z)\, \theta_y^z && \text{(Spin axis accel. coupling term)} \end{aligned}$$

$$+ H(\xi_x^z\dot{\Phi}_z - \xi_{ty}^z\dot{\Phi}_x)$$ (Misalignment term)

$$+ \frac{H[N_o - (N + \dot{\Phi}_z - \dot{\alpha}_t)]}{F_m}\ \theta_x^z$$ (Mistuning term)

$$+ H\frac{1}{\tau}\theta_y^z + D_r\dot{\theta}_x^z$$ (Damping term)

$$\pm HR_\theta\Phi_{2N}$$ (2N Angular Frequency term)

$$M_y^z = A(\ddot{\Phi}_y + \ddot{\theta}_y^z + \theta_x^z\ddot{\Phi}_z + \dot{\theta}_x^z\dot{\Phi}_z)$$ (Inertia term)

$$- H(\dot{\Phi}_x + \dot{\theta}_x^z - \theta_y^z\dot{\Phi}_z)$$ (Fundamental term)

$$- (C-A)(\dot{\Phi}_x + \dot{\theta}_x^z - \theta_y^z\dot{\Phi}_z)(\dot{\Phi}_z + \theta_y^z\dot{\Phi}_x - \theta_x^z\dot{\Phi}_y)$$ (Anisoinertia term)

$$- C\dot{\alpha}_t\ (\dot{\Phi}_x + \dot{\theta}_x^z - \theta_y^z\dot{\Phi}_z)$$ (Motor dynamics term)

$$- C(\ddot{\Phi}_z - \ddot{\alpha}_t^z)\ \theta_x^z$$ (Spin axis accel. coupling term)

$$- H(-\xi_y^z\dot{\Phi}_z + \xi_{tx}^z\dot{\Phi}_y)$$ (Misalignment term)

$$+ \frac{H[N_o - (N - \dot{\Phi}_z - \dot{\alpha}_t)]}{F_m}\ \theta_y^z$$ (Mistuning term)

$$- H\frac{1}{\tau}\theta_x^z + D_r\dot{\theta}_y^z$$ (Damping term)

$$\pm HR_\theta\Phi_{2N}$$ (2N Angular Frequency term)

The subscript denotes the axes of the ARU relative to which the quantity is measured and the superscripts specify the gyro which does the measuring. Note: The above equations were derived by R. Craig, Reference 6. M_x^z and M_y^z give the Z gyro model for angular inputs in terms of the moments that the gyro torquers exert on the rotor. Moment equations for X gyro (M_y^x, M_z^x) can be obtained by cyclic substitution of X for Z, Y for Z and Z for Y in Z-gyro model equation. Similarly, to obtain moment equations for Y-gyro (M_x^y, M_z^y) substitute X for Y, Y for Z and Z for X in Z-gyro model equations.

SECTION 4

TEST RESULTS

NASA LIFE TEST
PERFORMANCE TEST: DATA BASE
S/N 3334

SY:3334LIF4
12/27/95

PARAGRAPH	PARAMETER	UNITS	NOMINAL PERFORMANCE	TEST NO: #38 MEASURED TEST DATE 3/21/95 TESTER LISA D.	#39 MEASURED TEST DATE 4/21/95 TESTER LISA D.	#40 MEASURED TEST DATE 5/22/95 TESTER LISA D.	#41 MEASURED TEST DATE 6/22/95 TESTER LISA D.	#42 MEASURED TEST DATE 7/21/95 TESTER LISA D.	#43 MEASURED TEST DATE 8/24/95 TESTER LISA D.	#44 MEASURED TEST DATE 9/25/95 TESTER LISA D.	#45 MEASURED TEST DATE 11/27/95 TESTER LISA D.	#46 MEASURED TEST DATE 12/27/95 TESTER DS	AVERAGE	STANDARD DEVIATION 1 sigma
3.2.1	RUN UP TIME	SECONDS	< 15	10.30	10.70	10.55	10.30	10.95	10.95	10.25	10.75	10.90	10.89	0.20
3.2.2	MTR START CURRENT	MILLI-AMPS	< 150	75.67	75.68	75.44	75.02	74.68	74.94	74.83	74.84	74.64	76.25	1.48
3.2.3	MTR RUN CURRENT	MILLI-AMPS	< 150	34.25	33.42	33.77	33.24	33.67	33.36	34.37	32.90	32.17	33.71	1.30
3.2.4	MTR RUN-ON TIME	SECONDS	>20	65.77	67.59	65.50	67.88	75.24	70.44	67.61	69.79	73.85	68.74	5.30
3.2.5	SAH TUNED FREQ	HERTZ	397 - 403	396.8	396.9	396.9	396.3	396.9	396.8	396.3	396.3	396.8	396.9	0.1
3.2.6	SAV TUNED FREQ	HERTZ	393 - 401	394.2	394.3	394.2	394.2	394.2	394.9	394.2	394.3	394.3	394.4	0.1
3.2.7	TIME CONSTANT	SECONDS	> 15	18.6	18.5	19.4	18.9	18.5	18.6	19.6	18.6	17.8	18.6	0.4
3.2.8(A)	X PO OFFSET	ARC SECS	+/- 5	-2.4	-1.7	-1.4	-2.0	-1.2	-1.6	-2.1	-2.3	-1.5	-2.4	0.7
3.2.8(B)	Y PO OFFSET	ARC SECS	+/- 5	-2.0	-3.4	-2.9	-3.1	-3.5	-2.9	-3.7	-5.0	-2.6	-2.6	0.9
3.2.9(A)	X NULL QUAD	ARC SECS	+/- 20	8.34	8.86	8.34	7.95	8.60	8.34	8.60	8.81	8.86	8.37	0.37
3.2.9(B)	Y NULL QUAD	ARC SECS	+/- 20	8.93	8.93	8.93	8.01	8.93	8.15	7.75	7.72	8.40	8.21	0.74
3.2.10.1(A)	X TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2373	0.2373	0.2371	0.2373	0.2372	0.2374	0.2364	0.2376	0.2377	0.2372	0.0003
3.2.10.1(B)	Y TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2385	0.2386	0.2385	0.2385	0.2385	0.2383	0.2391	0.2383	0.2377	0.2384	0.0003
3.2.10.2(A)	X BIAS	DEG/HR	+/- 20	-0.372	-0.397	-0.258	-0.366	-0.341	-0.275	-0.277	-0.352	-0.278	-0.382	0.082
3.2.10.2(B)	Y BIAS	DEG/HR	+/- 20	-1.098	-1.240	-1.184	-1.174	-1.281	-1.203	-1.139	-0.986	-1.081	-1.163	0.063
3.2.10.3(A)	X DIRECT MASS UNB	DEG/HR/G	+/- 10	1.979	2.012	2.025	2.007	1.980	1.927	1.906	1.955	2.007	2.109	0.154
3.2.10.3(B)	Y DIRECT MASS UNB	DEG/HR/G	+/- 10	2.025	2.079	2.048	2.032	2.014	1.993	2.058	1.965	1.954	2.165	0.149
3.2.10.4(A)	X QUAD MASS UNBAL	DEG/HR/G	+/- 10	-2.914	-2.881	-2.876	-2.836	-2.860	-2.833	-2.714	-2.874	-2.834	-2.921	0.070
3.2.10.4(B)	Y QUAD MASS UNBAL	DEG/HR/G	+/- 10	2.841	2.812	2.788	2.844	2.748	2.767	2.710	2.696	2.781	2.851	0.066

** NOTE: Prior to Test #14 the PO Supply Board Demod Ref. was modified.

NASA LIFE TEST
PERFORMANCE TEST: DATA BASE
S/N 3334

SY:3334LIF3
2/21/95

PARAGRAPH	PARAMETER	UNITS	NOMINAL PERFORMANCE	#25 MEASURED TEST DATE 1/27/94 TESTER WEBB D.	#26 MEASURED TEST DATE 2/28/94 TESTER WEBB D.	#27 MEASURED TEST DATE 4/6/94 TESTER WEBB D.	#28 MEASURED TEST DATE 5/10/94 TESTER LISA D.	#29 MEASURED TEST DATE 6/10/94 TESTER LISA D.	#30 MEASURED TEST DATE 7/11/94 TESTER AMYN	#31 MEASURED TEST DATE 8/8/94 TESTER LISA D.	#32 MEASURED TEST DATE 9/7/94 TESTER LISA D.	#33 MEASURED TEST DATE 10/10/94 TESTER LISA D.	#34 MEASURED TEST DATE 11/10/94 TESTER LISA D.	#35 MEASURED TEST DATE 12/9/94 TESTER LISA D.	#36 MEASURED TEST DATE 1/12/95 TESTER LISA D.	#37 MEASURED TEST DATE 2/21/95 TESTER LISA D.
3.2.1	RUN UP TIME	SECONDS	< 16	11.10	11.15	10.70	11.20	11.00	10.75	10.80	10.65	11.00	10.75	10.85	11.15	10.85
3.2.2	MTR START CURRENT	MILLI-AMPS	< 150	76.55	80.91	77.30	78.25	79.87	78.09	75.26	74.89	74.98	74.93	76.11	77.86	75.46
3.2.3	MTR RUN CURRENT	MILLI-AMPS	< 150	33.38	35.40	33.72	33.72	34.09	34.82	33.38	32.82	34.16	33.63	35.31	33.11	33.79
3.2.4	MTR RUN-DN TIME	SECONDS	>20	63.03	62.29	75.38	69.62	70.54	69.57	65.87	65.77	74.91	63.68	60.10	62.32	62.60
3.2.5	SAH TUNED FREQ	HERTZ	397 - 403	397.0	397.0	396.6	396.9	396.9	396.9	396.9	396.9	396.9	396.9	396.9	396.8	396.8
3.2.6	SAV TUNED FREQ	HERTZ	393 - 401	394.4	394.4	394.4	394.4	394.4	394.3	394.3	394.3	394.3	394.3	394.4	394.2	394.2
3.2.7	TIME CONSTANT	SECONDS	> 15	18.7	18.7	18.7	18.6	18.6	18.9	17.4	18.6	18.6	18.6	18.7	18.6	18.6
3.2.8(A)	X PO OFFSET	ARC SECS	+/- 6	-3.1	-3.3	-3.4	-1.8	-2.2	-2.7	-2.5	-2.6	-2.1	-2.3	-3.6	-3.2	-2.2
3.2.8(B)	Y PO OFFSET	ARC SECS	+/- 6	-2.7	-3.2	-1.2	-1.9	-2.3	-3.0	-2.1	-2.3	-2.3	-3.6	-4.1	-4.6	-2.9
3.2.9(A)	X NULL QUAD	ARC SECS	+/- 20	8.60	8.60	8.50	8.34	8.34	8.08	7.77	7.82	8.08	8.86	9.12	8.86	8.34
3.2.9(B)	Y NULL QUAD	ARC SECS	+/- 20	8.40	8.90	7.90	8.41	7.59	7.62	8.41	8.15	7.75	8.41	9.46	9.46	9.20
3.2.10.1(A)	X TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2372	0.2371	0.2372	0.2373	0.2376	0.2370	0.2373	0.2374	0.2373	0.2373	0.2374	0.2366	0.2377
3.2.10.1(B)	Y TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2383	0.2384	0.2384	0.2385	0.2383	0.2385	0.2384	0.2381	0.2384	0.2384	0.2385	0.2384	0.2384
3.2.10.2(A)	X BIAS	DEG/HR	+/- 20	-0.584	-0.522	-0.376	-0.354	-0.291	-0.477	-0.323	-0.355	-0.457	-0.386	-0.511	-0.465	-0.379
3.2.10.2(B)	Y BIAS	DEG/HR	+/- 20	-1.102	-1.159	-1.035	-1.199	-1.226	-1.137	-1.138	-1.165	-1.229	-1.215	-1.100	-1.165	-1.165
3.2.10.3(A)	X DIRECT MASS UNB	DEG/HR/G	+/- 10	2.094	2.103	2.053	2.099	2.098	1.991	1.993	2.022	1.996	1.977	2.017	2.044	1.999
3.2.10.3(B)	Y DIRECT MASS UNB	DEG/HR/G	+/- 10	2.183	2.182	2.135	2.188	2.128	2.108	2.105	2.076	2.117	2.061	2.116	2.065	1.990
3.2.10.4(A)	X QUAD MASS UNBAL	DEG/HR/G	+/- 10	-2.903	-2.928	-2.910	-2.975	-2.972	-2.899	-2.895	-2.896	-2.877	-2.912	-2.902	-2.887	-2.942
3.2.10.4(B)	Y QUAD MASS UNBAL	DEG/HR/G	+/- 10	2.845	2.878	2.848	2.947	2.863	2.858	2.846	2.846	2.863	2.805	2.837	2.837	2.811

** NOTE: Prior to Test #14 the PO Supply Board Demod Ref. was modified.

NASA LIFE TEST
PERFORMANCE TEST: DATA BASE
S/N 3334

BY:3334LIFE
MARCH 08,1994

PARAGRAPH	PARAMETER	UNITS	NOMINAL PERFORMANCE	#14 MEASURED TEST DATE 03/16/93 TESTER LISA D.	#15 MEASURED TEST DATE 04/13/93 TESTER LISA D.	#16 MEASURED TEST DATE 05/11/93 TESTER LISA D.	#17 MEASURED TEST DATE 06/08/93 TESTER LISA D.	#18 MEASURED TEST DATE 07/06/93 TESTER LISA D.	#19 MEASURED TEST DATE 08/03/93 TESTER LISA D.	#20 MEASURED TEST DATE 8/31/93 TESTER LISA D.	#21 MEASURED TEST DATE 9/28/93 TESTER LISA D.	#22 MEASURED TEST DATE 10/26/93 TESTER WEBB D.	#23 MEASURED TEST DATE 11/23/93 TESTER WEBB D.	#24 MEASURED TEST DATE 12/27/93 TESTER WEBB D.
3.2.1	RUN UP TIME	SECONDS	< 15	10.85	11.10	10.90	10.80	10.95	10.70	11.00	11.20	11.15	11.05	11.00
3.2.2	MTR START CURRENT	MILLI-AMPS	< 150	75.64	76.59	76.94	75.68	75.94	77.53	75.57	76.23	75.69	76.60	77.67
3.2.3	MTR RUN CURRENT	MILLI-AMPS	< 150	32.23	32.40	32.90	36.66	32.28	32.59	31.30	38.37	33.06	33.75	33.82
3.2.4	MTR RUN-ON TIME	SECONDS	>20	78.39	78.43	65.25	73.49	70.89	78.25	70.44	68.00	61.95	59.93	74.15
3.2.5	SAH TUNED FREQ	HERTZ	397 - 403	397.1	397.1	397.1	397.1	397.1	397.1	397.1	397.1	397.0	397.0	397.0
3.2.6	SAV TUNED FREQ	HERTZ	393 - 401	394.5	394.5	394.5	394.5	394.5	394.5	394.5	394.5	394.4	394.4	394.4
3.2.7	TIME CONSTANT	SECONDS	> 15	18.9	19.0	18.8	19.9	18.9	18.8	19.9	19.2	19.7	18.7	18.6
3.2.8(A)	X PO OFFSET	ARC SECS	+/- 6	-2.7	-2.9	-4.0	-1.8	-1.7	-1.9	-2.2	-2.3	-3.3	-2.5	-2.9
3.2.8(B)	Y PO OFFSET	ARC SECS	+/- 6	-1.9	-2.4	-1.9	-1.5	-2.1	-1.6	-1.0	-2.6	-2.2	-2.4	-2.0
3.2.9(A)	X NULL QUAD	ARC SECS	+/- 20	8.08	7.82	8.60	8.34	8.07	8.08	7.53	8.08	8.33	8.60	8.60
3.2.9(B)	Y NULL QUAD	ARC SECS	+/- 20	7.36	6.95	7.98	7.62	7.40	7.09	6.70	7.62	8.66	9.70	8.41
3.2.10.1(A)	X TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2374	0.2373	0.2374	0.2373	0.2373	0.2374	0.2371	0.2373	0.2372	0.2372	0.2362
3.2.10.1(B)	Y TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2389	0.2387	0.2386	0.2383	0.2388	0.2390	0.2379	0.2384	0.2384	0.2385	0.2378
3.2.10.2(A)	X BIAS	DEG/HR	+/- 20	-0.329	-0.466	-0.320	-.250	-0.307	-0.385	-0.404	-0.443	-0.525	-0.408	-0.348
3.2.10.2(B)	Y BIAS	DEG/HR	+/- 20	-1.174	-1.213	-1.163	-.232	-1.260	-1.180	-1.142	-1.195	-1.092	-1.214	-1.098
3.2.10.3(A)	X DIRECT MASS UNB	DEG/HR/G	+/- 10	2.451	2.391	2.373	.325	2.352	2.357	2.332	2.265	2.139	2.149	2.190
3.2.10.3(B)	Y DIRECT MASS UNB	DEG/HR/G	+/- 10	2.470	2.443	2.397	.353	2.403	2.393	2.341	2.365	2.174	2.230	2.242
3.2.10.4(A)	X QUAD MASS UNBAL	DEG/HR/G	+/- 10	-2.968	-2.999	-2.999	-.958	-3.012	-3.082	-3.042	-2.996	-2.931	-2.961	-2.903
3.2.10.4(B)	Y QUAD MASS UNBAL	DEG/HR/G	+/- 10	2.875	2.931	2.932	.721	2.933	2.962	2.964	2.926	2.838	2.903	2.832

** NOTE: Prior to Test #14 the PO Supply Board Demod Ref. was modified.

NASA LIFE TEST SY:2224LIF1
PERFORMANCE TEST: DATA BASE 07/20/93
S/N 2224

NOTE: BASELINE, TEST #2 & TEST #12 REMOVED FOR AVERAGE AND STANDARD DEVIATION CALCULATIONS *

PARAGRAPH	PARAMETER	UNITS	NOMINAL PERFORMANCE	BASELINE MEASURED TEST DATE 09/11/92 TESTER MIKE N.	#2 MEASURED TEST DATE 09/25/92 TESTER LISA D.	#3 MEASURED TEST DATE 10/09/92 TESTER MIKE N.	#4 MEASURED TEST DATE 10/26/92 TESTER MIKE N.	#5 MEASURED TEST DATE 11/09/92 TESTER LISA D.	#6 MEASURED TEST DATE 11/23/92 TESTER MIKE N.	#7 MEASURED TEST DATE 12/07/92 TESTER MIKE N.	#8 MEASURED TEST DATE 12/21/92 TESTER MIKE N.	#9 MEASURED TEST DATE 01/04/93 TESTER MIKE N.	#10 MEASURED TEST DATE 01/19/93 TESTER MIKE N.	#11 MEASURED TEST DATE 02/01/93 TESTER LISA D.	#12 MEASURED TEST DATE 02/16/93 TESTER WEBB D.	#13 MEASURED TEST DATE 03/02/93 TESTER LISA D.
3.2.1	RUN UP TIME	SECONDS	< 16	10.65	10.75	10.65	11.[illegible]5	10.80	10.50	10.70	10.70	10.55	10.35	10.85	10.05	10.85
3.2.2	MTR START CURRENT	MILLI-AMPS	< 150	74.77	75.19	75.07	74.[illegible]7	74.90	74.66	75.36	75.00	75.04	74.96	75.63	75.98	76.26
3.2.3	MTR RUN CURRENT	MILLI-AMPS	< 150	31.59	31.36	33.18	31.[illegible]8	31.27	31.62	30.96	31.62	30.01	31.82	34.75	32.45	32.21
3.2.4	MTR RUN-ON TIME	SECONDS	> 20	60.01	78.46	73.74	71.[illegible]3	77.49	84.40	84.17	101.95	104.42	94.82	59.28	99.56	91.30
3.2.5	SAH TUNED FREQ	HERTZ	397 - 403	397.2	397.2	397.2	397.2	397.2	397.1	397.1	397.1	397.1	397.1	397.1	397.2	397.1
3.2.6	SAV TUNED FREQ	HERTZ	393 - 401	394.6	394.6	394.6	394.5	394.6	394.6	394.5	394.6	394.5	394.6	394.5	394.6	394.5
3.2.7	TIME CONSTANT	SECONDS	> 15	19.3	19.1	19.0	18.4	18.1	19.0	18.7	18.7	18.4	18.9	19.0	19.2	19.3
3.2.8(A)	X PO OFFSET	ARC SECS	+/- 6	-0.6	-4.0	-3.5	-3.6	-3.6	-3.6	-2.3	-3.0	-3.0	-3.7	-3.4	-4.2	-3.3
3.2.8(B)	Y PO OFFSET	ARC SECS	+/- 6	0.4	4.6	5.0	4.4	4.6	3.6	3.3	3.6	4.5	4.5	3.9	4.5	3.2
3.2.9(A)	X NULL QUAD	ARC SECS	+/- 20	2.20	2.60	8.27	0.02	7.81	7.81	8.33	8.07	8.07	8.72	8.85	7.29	8.85
3.2.9(B)	Y NULL QUAD	ARC SECS	+/- 20	1.40	2.60	7.00	0.01	6.56	6.82	7.08	6.82	6.29	7.35	7.87	8.13	6.43
3.2.10.1(A)	X TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2371	0.2370	0.2370	0.2370	0.2370	0.2370	0.2370	0.2370	0.2370	0.2370	0.2373	0.2372	0.2371
3.2.10.1(B)	Y TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2389	0.2380	0.2380	0.2380	0.2385	0.2390	0.2390	0.2390	0.2380	0.2390	0.2389	0.2387	0.2386
3.2.10.2(A)	X BIAS	DEG/HR	+/- 20	-0.560	-0.129	-0.026	-0.087	0.009	-0.029	-0.013	0.011	-0.012	-0.068	-0.068	-0.081	-0.120
3.2.10.2(B)	Y BIAS	DEG/HR	+/- 20	-1.027	-0.549	-0.645	-0.627	-0.593	-0.689	-0.888	-0.785	-0.729	-0.729	-0.741	-0.499	-0.801
3.2.10.3(A)	X DIRECT MASS UNB	DEG/HR/G	+/- 10	2.612	2.577	2.520	2.557	2.523	2.531	2.519	2.484	2.474	2.488	2.487	2.532	2.446
3.2.10.3(B)	Y DIRECT MASS UNB	DEG/HR/G	+/- 10	2.636	2.590	2.554	2.584	2.540	2.552	2.569	2.513	2.507	2.496	2.515	2.546	2.498
3.2.10.4(A)	X QUAD MASS UNBAL	DEG/HR/G	+/- 10	-3.085	-3.063	-2.992	-3.055	-3.090	-3.098	-3.078	-3.031	-3.051	-3.051	-3.067	-3.102	-3.060
3.2.10.4(B)	Y QUAD MASS UNBAL	DEG/HR/G	+/- 10	3.031	3.011	2.869	2.948	3.014	3.019	3.002	2.992	2.984	2.944	3.005	2.988	3.039

* NOTE: Test #12 was performed using the wrong test cube & dreamo electronics.

NASA LIFE TEST
PERFORMANCE TEST: DATA BASE
S/N 3327

SY:3327LIF4
12/27/95

PARAGRAPH	PARAMETER	UNITS	NOMINAL PERFORMANCE	#32 MEASURED TEST DATE 12/12/94 TESTER LISA D.	#33 MEASURED TEST DATE 1/12/95 TESTER LISA D.	#34 MEASURED TEST DATE 2/21/95 TESTER LISA D.	#3 MEASUED TEST ATE 3/21/ TESTE LISA	#36 MEASURED TEST DATE 4/21/95 TESTER LISA D.	#37 MEASURED TEST DATE 5/22/95 TESTER LISA D.	#38 MEASURED TEST DATE 6/22/95 TESTER LISA D.	#39 MEASURED TEST DATE 7/21/95 TESTER LISA D.	#40 MEASURED TEST DATE 8/24/95 TESTER LISA D.	#41 MEASURED TEST DATE 9/25/95 TESTER DS	#42 MEASURED TEST DATE 10/27/95 TESTER LISA D.	#43 MEASURED TEST DATE 11/27/95 TESTER LISA D	#44 MEASURED TEST DATE 12/27/95 TESTER DS	AVERAGE	STANDARD DEVIATION 1 sigma
3.2.1	RUN UP TIME	SECONDS	< 16	11.40	11.75	11.40	11.60	11.35	11.40	11.10	11.10	11.65	11.90	11.60	11.60	11.40	11.25	0.37
3.2.2	MTR START CURRENT	MILLI-AMPS	< 150	78.38	78.64	78.05	79.16	79.05	77.35	76.94	76.77	77.11	77.07	77.61	77.06	77.26	78.38	2.04
3.2.3	MTR RUN CURRENT	MILLI-AMPS	< 150	41.62	42.04	37.50	36.06	43.39	36.17	35.57	40.34	36.12	38.87	37.65	36.01	36.07	37.64	2.37
3.2.4	MTR RUN-ON TIME	SECONDS	> 20	51.74	50.69	57.91	55.84	49.54	61.68	58.93	52.75	63.78	51.61	51.83	61.00	56.92	59.35	8.26
3.2.5	SAH TUNED FREQ	HERTZ	397 - 403	398.3	398.3	398.3	398.3	398.3	398.3	398.3	398.3	398.3	398.3	398.3	398.3	398.3	398.3	0.1
3.2.6	SAV TUNED FREQ	HERTZ	393 - 401	395.9	395.9	395.9	395.9	395.9	395.9	395.9	395.9	395.9	395.9	395.9	395.9	395.9	395.9	0.1
3.2.7	TIME CONSTANT	SECONDS	> 15	17.4	17.3	17.3	17.4	17.5	16.8	16.8	17.3	17.3	17.3	17.3	17.4	17.3	17.5	0.3
3.2.8(A)	X PO OFFSET	ARC SECS	+/- 6	-5.5	-4.1	-5.6	-6.0	-5.0	-5.3	-6.0	-5.2	-4.9	-5.5	-4.6	-6.2	-4.7	-5.1	0.7
3.2.8(B)	Y PO OFFSET	ARC SECS	+/- 6	7.2	6.3	7.8	7.8	7.4	7.6	6.8	7.3	7.3	7.2	7.7	7.7	7.6	7.4	0.4
3.2.9(A)	X NULL QUAD	ARC SECS	+/- 20	2.61	0.99	2.22	2.87	2.14	2.27	2.61	2.48	2.55	2.48	1.62	3.00	2.92	2.25	0.53
3.2.9(B)	Y NULL QUAD	ARC SECS	+/- 20	1.74	1.38	1.66	1.38	1.58	1.63	1.53	1.48	1.43	1.40	1.48	0.73	1.48	1.02	0.55
3.2.10.1(A)	X TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2336	0.2335	0.2336	0.2341	0.2334	0.2336	0.2335	0.2334	0.2349	0.2341	0.2333	0.2334	0.2332	0.2337	0.0003
3.2.10.1(B)	Y TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2390	0.2386	0.2385	0.2389	0.2385	0.2387	0.2387	0.2386	0.2378	0.2391	0.2390	0.2384	0.2380	0.2386	0.0003
3.2.10.2(A)	X BIAS	DEG/HR	+/- 20	-3.452	-3.439	-3.402	-3.511	-3.494	-3.386	-3.381	-3.363	-3.381	-3.606	-3.594	-3.591	-3.602	-3.502	0.099
3.2.10.2(B)	Y BIAS	DEG/HR	+/- 20	-17.162	-17.189	-17.181	-17.194	-17.200	-17.322	-17.337	-17.303	-17.209	-17.227	-17.264	-17.164	-17.017	-17.135	0.144
3.2.10.3(A)	X DIRECT MASS UNB	DEG/HR/G	+/- 10	-4.338	-4.407	-4.417	-4.362	-4.372	-4.417	-4.440	-4.417	-4.448	-4.410	-4.463	-4.447	-4.387	-4.349	0.090
3.2.10.3(B)	Y DIRECT MASS UNB	DEG/HR/G	+/- 10	-4.428	-4.434	-4.423	-4.346	-4.447	-4.417	-4.456	-4.450	-4.434	-4.417	-4.419	-4.424	-4.406	-4.373	0.090
3.2.10.4(A)	X QUAD MASS UNBAL	DEG/HR/G	+/- 10	-0.593	-0.627	-0.619	-0.594	-0.634	-0.629	-0.632	-0.629	-0.638	-0.623	-0.625	-0.659	-0.609	-0.626	0.024
3.2.10.4(B)	Y QUAD MASS UNBAL	DEG/HR/G	+/- 10	0.499	0.506	0.542	0.547	0.490	0.517	0.537	0.529	0.552	0.558	0.522	0.546	0.540	0.529	0.030

** NOTE: Prior to Test #7 the P.O. Supply Board Demod Referance was modified.

NASA LIFE TEST
PERFORMANCE TEST: DATA BASE
S/N 3327

BY:3327LIF3
11/10/94

PARAGRAPH	PARAMETER	UNITS	NOMINAL PERFORMANCE	#19 MEASURED TEST DATE 11/11/93 TESTER WEBB D.	#20 MEASURED TEST DATE 12/9/93 TESTER WEBB D.	#21 MEASURED TEST DATE 1/6/94 TESTER WEBB D.	#22 MEASURED TEST DATE 2/3/94 TESTER WEBB D.	#23 MEASURED TEST DATE 3/2/94 TESTER AMYN C.	#24 MEASURED TEST DATE 4/12/94 TESTER WEBB D.	#25 MEASURED TEST DATE 5/10/94 TESTER LISA D.	#26 MEASURED TEST DATE 6/9/94 TESTER LISA D.	#27 MEASURED TEST DATE 7/11/94 TESTER AMYN	#28 MEASURED TEST DATE 8/8/94 TESTER LISA D.	#29 MEASURED TEST DATE 9/9/94 TESTER LISA D.	#30 MEASURED TEST DATE 10/10/94 TESTER LISA D.	#31 MEASURED TEST DATE 11/10/94 TESTER LISA D.
3.2.1	RUN UP TIME	SECONDS	< 15	11.25	11.00	11.10	1.65	10.90	11.30	11.10	11.75	11.00	11.45	11.35	11.35	11.30
3.2.2	MTR START CURRENT	MILLI-AMPS	< 150	77.00	80.14	78.10	8.61	80.35	79.27	81.79	88.64	77.43	78.78	77.15	76.77	76.75
3.2.3	MTR RUN CURRENT	MILLI-AMPS	< 150	37.10	40.06	37.01	0.85	39.10	37.58	38.27	42.61	36.73	39.75	37.59	37.71	40.83
3.2.4	MTR RUN-ON TIME	SECONDS	> 20	59.20	54.57	59.40	5.14	62.78	46.91	49.65	49.60	55.00	50.58	62.84	53.59	53.73
3.2.5	SAH TUNED FREQ	HERTZ	397 - 403	398.3	398.3	398.3	98.3	398.3	398.3	398.2	398.3	398.3	398.3	398.3	398.3	398.3
3.2.6	SAV TUNED FREQ	HERTZ	393 - 401	395.9	395.9	395.9	95.9	395.9	395.9	395.8	395.9	395.9	395.9	395.9	395.9	395.9
3.2.7	TIME CONSTANT	SECONDS	> 15	17.5	17.5	17.6	17.6	17.4	17.3	17.4	17.5	17.4	17.5	17.3	17.4	16.3
3.2.8(A)	X PO OFFSET	ARC SECS	+/- 6	-4.5	-5.2	-5.3	-5.5	-6.0	-5.6	-5.0	-5.4	-5.8	-5.6	-6.2	-6.0	-5.6
3.2.8(B)	Y PO OFFSET	ARC SECS	+/- 6	7.5	7.3	7.6	8.2	7.8	7.8	7.7	7.6	7.4	7.2	6.6	6.9	7.4
3.2.9(A)	X NULL QUAD	ARC SECS	+/- 20	1.69	1.72	1.54	.70	1.62	1.02	1.83	2.48	2.50	2.55	2.22	2.40	2.40
3.2.9(B)	Y NULL QUAD	ARC SECS	+/- 20	1.02	0.31	0.59	.40	0.66	1.64	0.41	1.74	1.68	1.58	1.48	1.38	1.53
3.2.10.1(A)	X TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2337	0.2336	0.2329	0.2335	0.2336	0.2338	0.2334	0.2335	0.2338	0.2338	0.2335	0.2337	0.2341
3.2.10.1(B)	Y TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2385	0.2367	0.2379	0.2385	0.2385	0.2386	0.2384	0.2386	0.2387	0.2386	0.2384	0.2386	0.2383
3.2.10.2(A)	X BIAS	DEG/HR	+/- 20	-3.491	-3.668	-3.458	-3.617	-3.637	-3.321	-3.512	-3.509	-3.463	-3.475	-3.426	-3.405	-3.539
3.2.10.2(B)	Y BIAS	DEG/HR	+/- 20	-17.171	-17.050	-16.996	-17.137	-16.963	-17.389	-17.253	-17.262	-17.350	-17.338	-17.214	-17.318	-17.202
3.2.10.3(A)	X DIRECT MASS UNB	DEG/HR/G	+/- 10	-4.367	-4.396	-4.433	-4.392	-4.368	-4.432	-4.449	-4.374	-4.412	-4.456	-4.400	-4.419	-4.363
3.2.10.3(B)	Y DIRECT MASS UNB	DEG/HR/G	+/- 10	-4.405	-4.434	-4.424	-4.399	-4.391	-4.460	-4.523	-4.493	-4.454	-4.396	-4.441	-4.434	-4.408
3.2.10.4(A)	X QUAD MASS UNBAL	DEG/HR/G	+/- 10	-0.620	-0.606	-0.571	-0.627	-0.627	-0.591	-0.641	-0.637	-0.608	-0.586	-0.608	-0.618	-0.645
3.2.10.4(B)	Y QUAD MASS UNBAL	DEG/HR/G	+/- 10	0.516	0.482	0.450	0.552	0.544	0.519	0.526	0.554	0.524	0.572	0.562	0.547	0.551

** NOTE: Prior to Test #7 the P.O. Supply Board Demod Reference was modified.

NASA LIFE TEST
PERFORMANCE TEST: DATA BASE
S/N 3327

SY:3327LIFE
12/29/93

PARAGRAPH	PARAMETER	UNITS	NOMINAL PERFORMANCE	#7 MEASURED TEST DATE 03/17/93 TESTER LISA D.	#8 MEASURED TEST DATE 04/01/93 TESTER LISA D.	#9 MEASURED TEST DATE 04/15/93 TESTER LISA D.	#10 MEASURE TEST DATE 4/29/93 TESTER LISA D.	#11 MEASURED TEST DATE 5/13/93 TESTER LISA D.	#12 MEASURED TEST DATE 5/27/93 TESTER LISA D.	#13 MEASURED TEST DATE 06/10/93 TESTER LISA D.	#14 MEASURED TEST DATE 06/24/93 TESTER LISA D.	#15 MEASURED TEST DATE 7/22/93 TESTER LISA D.	#16 MEASURED TEST DATE 8/19/93 TESTER LISA D.	#17 MEASURED TEST DATE 9/16/93 TESTER LISA D.	#18 MEASURED TEST DATE 10/14/93 TESTER WEBB D.
3.2.1	RUN UP TIME	SECONDS	< 16	11.15	10.90	10.35	11.10	10.90	10.75	11.50	10.40	10.95	11.05	10.55	11.00
3.2.2	MTR START CURRENT	MILLI-AMPS	< 150	77.76	77.75	77.61	77.51	77.76	77.67	77.19	77.39	78.29	80.34	79.15	77.56
3.2.3	MTR RUN CURRENT	MILLI-AMPS	< 150	34.67	34.97	34.66	36.34	34.60	34.98	36.74	36.29	35.72	35.05	36.55	36.65
3.2.4	MTR RUN-ON TIME	SECONDS	> 20	65.07	64.27	67.20	66.98	70.82	72.79	70.05	69.49	68.43	64.03	73.09	77.34
3.2.5	SAH TUNED FREQ	HERTZ	397 - 403	398.5	398.5	398.5	398.4	398.4	398.4	398.4	398.4	398.4	398.4	398.4	398.6
3.2.6	SAV TUNED FREQ	HERTZ	393 - 401	396.1	396.1	396.1	396.0	396.0	396.0	396.0	396.0	396.0	396.0	396.0	396.4
3.2.7	TIME CONSTANT	SECONDS	> 15	17.9	17.9	17.8	17.8	17.8	17.7	17.8	17.8	17.7	17.7	17.7	17.6
3.2.8(A)	X PO OFFSET	ARC SECS	+/- 6	-4.0	-4.2	-3.7	-4.5	-4.3	-4.3	-3.9	-4.0	-5.0	-3.9	-5.2	-5.3
3.2.8(B)	Y PO OFFSET	ARC SECS	+/- 6	6.5	7.5	7.6	7.3	6.6	7.3	7.5	7.5	6.8	7.7	7.5	8.4
3.2.9(A)	X NULL QUAD	ARC SECS	+/- 20	2.87	2.74	2.22	2.53	2.24	2.45	3.00	2.76	1.93	3.05	1.75	1.53
3.2.9(B)	Y NULL QUAD	ARC SECS	+/- 20	0.33	0.23	0.10	0.49	0.54	0.68	0.66	0.43	0.69	0.38	0.48	0.32
3.2.10.1(A)	X TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2338	0.2336	0.2336	0.2337	0.2340	0.2338	0.2340	0.2337	0.2339	0.2337	0.2339	0.2337
3.2.10.1(B)	Y TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2387	0.2383	0.2387	0.2386	0.2389	0.2386	0.2384	0.2388	0.2392	0.2387	0.2387	0.2386
3.2.10.2(A)	X BIAS	DEG/HR	+/- 20	-3.556	-3.436	-3.451	-3.521	-3.455	-3.335	-3.578	-3.568	-3.500	-3.586	-3.781	-3.581
3.2.10.2(B)	Y BIAS	DEG/HR	+/- 20	-16.922	-16.907	-17.020	-16.993	-17.025	-17.061	-16.948	-17.081	-17.008	-16.954	-16.870	-16.945
3.2.10.3(A)	X DIRECT MASS UNB	DEG/HR/G	+/- 10	-4.220	-4.204	-4.234	-4.217	-4.229	-4.240	-4.232	-4.250	-4.220	-4.208	-4.207	-4.211
3.2.10.3(B)	Y DIRECT MASS UNB	DEG/HR/G	+/- 10	-4.242	-4.297	-4.299	-4.229	-4.254	-4.278	-4.214	-4.212	-4.233	-4.276	-4.213	-4.246
3.2.10.4(A)	X QUAD MASS UNBAL	DEG/HR/G	+/- 10	-0.606	-0.681	-0.623	-0.622	-0.608	-0.624	-0.643	-0.649	-0.673	-0.659	-0.636	-0.680
3.2.10.4(B)	Y QUAD MASS UNBAL	DEG/HR/G	+/- 10	0.465	0.540	0.501	0.508	0.533	0.529	0.523	0.537	0.591	0.517	0.610	0.505

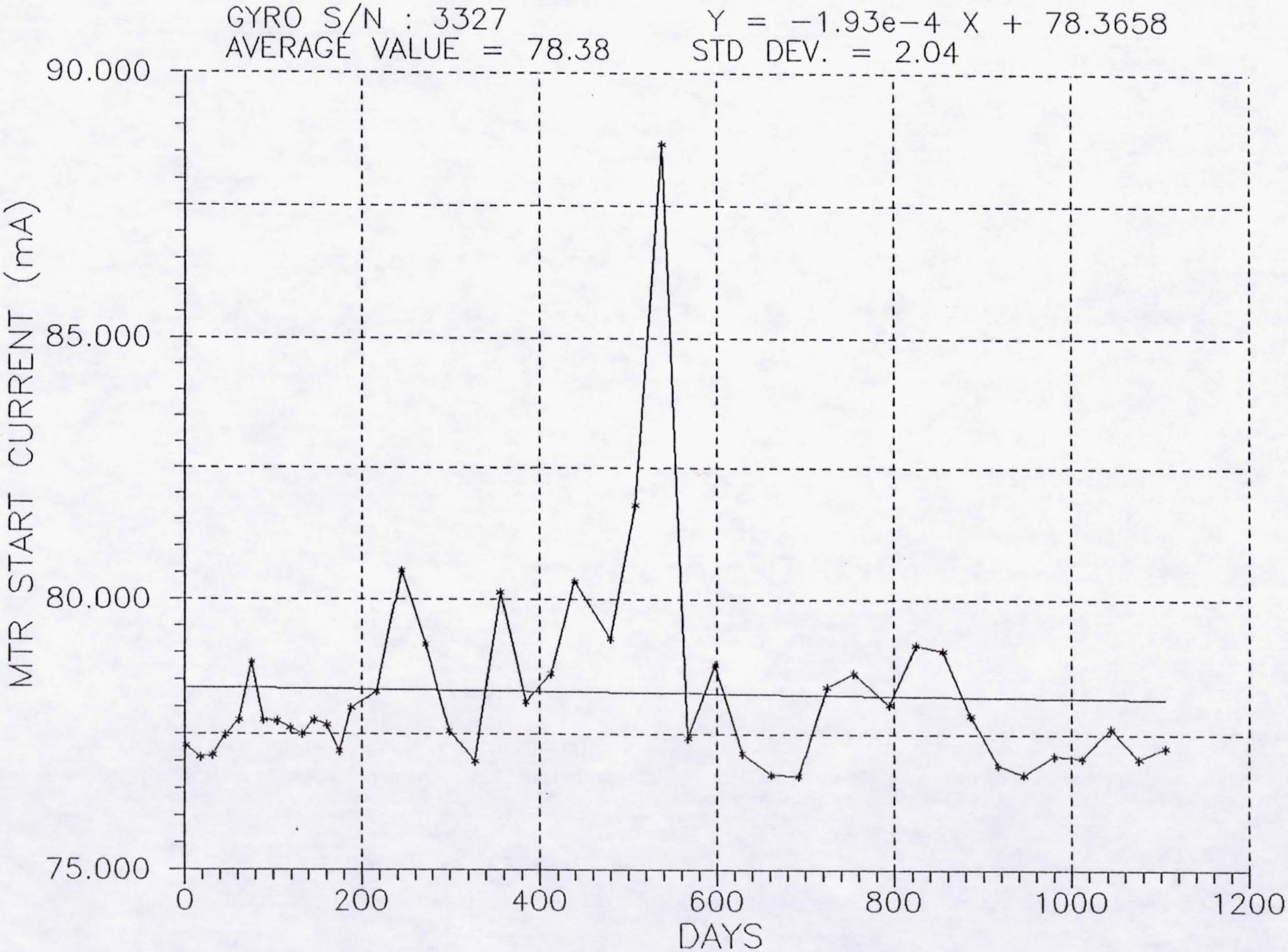
** NOTE: Prior to Test #7 the P.O. Supply Board Demod Referance was modified.

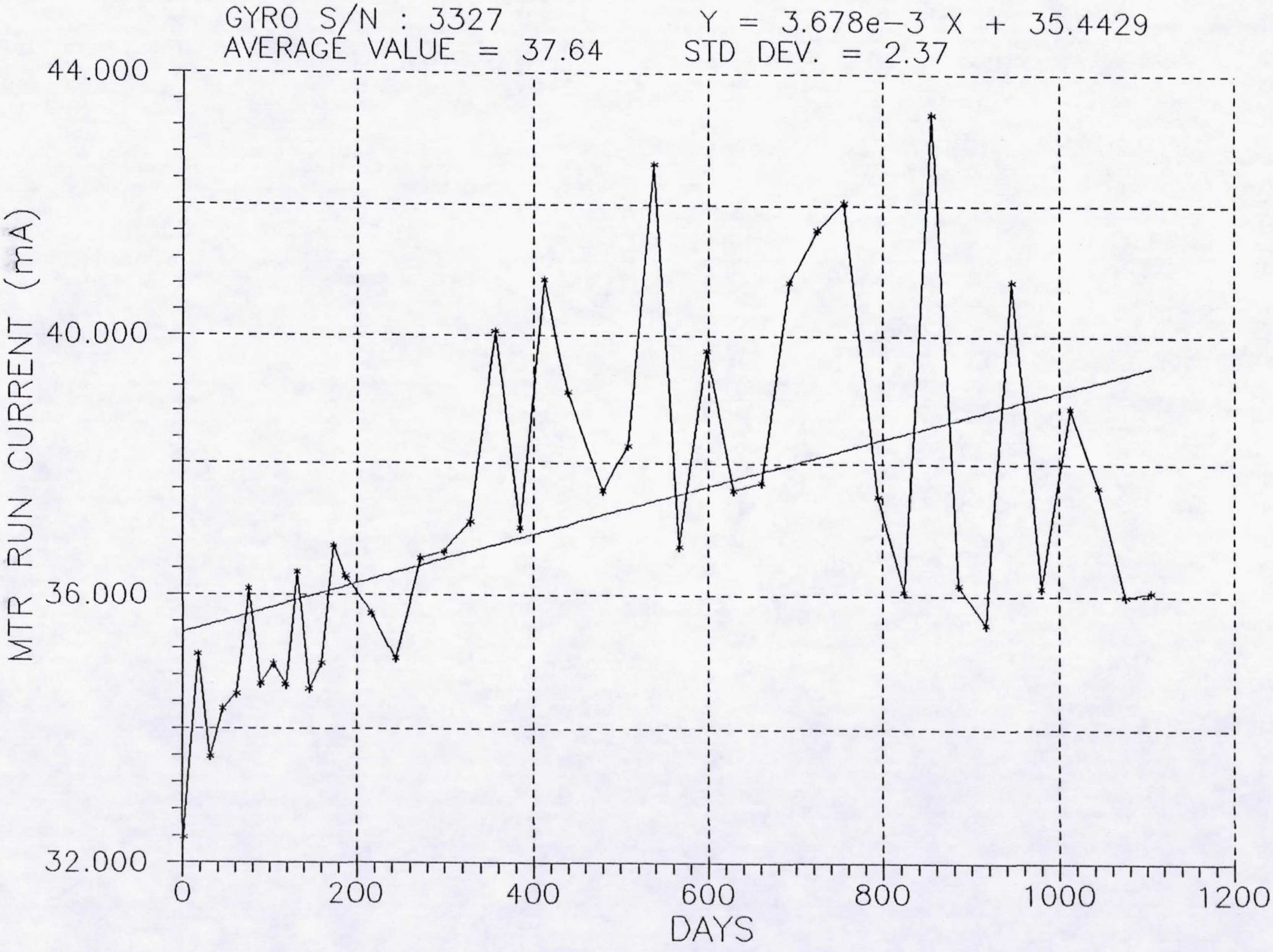
NASA LIFE TEST
PERFORMANCE TEST: DATA BASE
S/N 3327

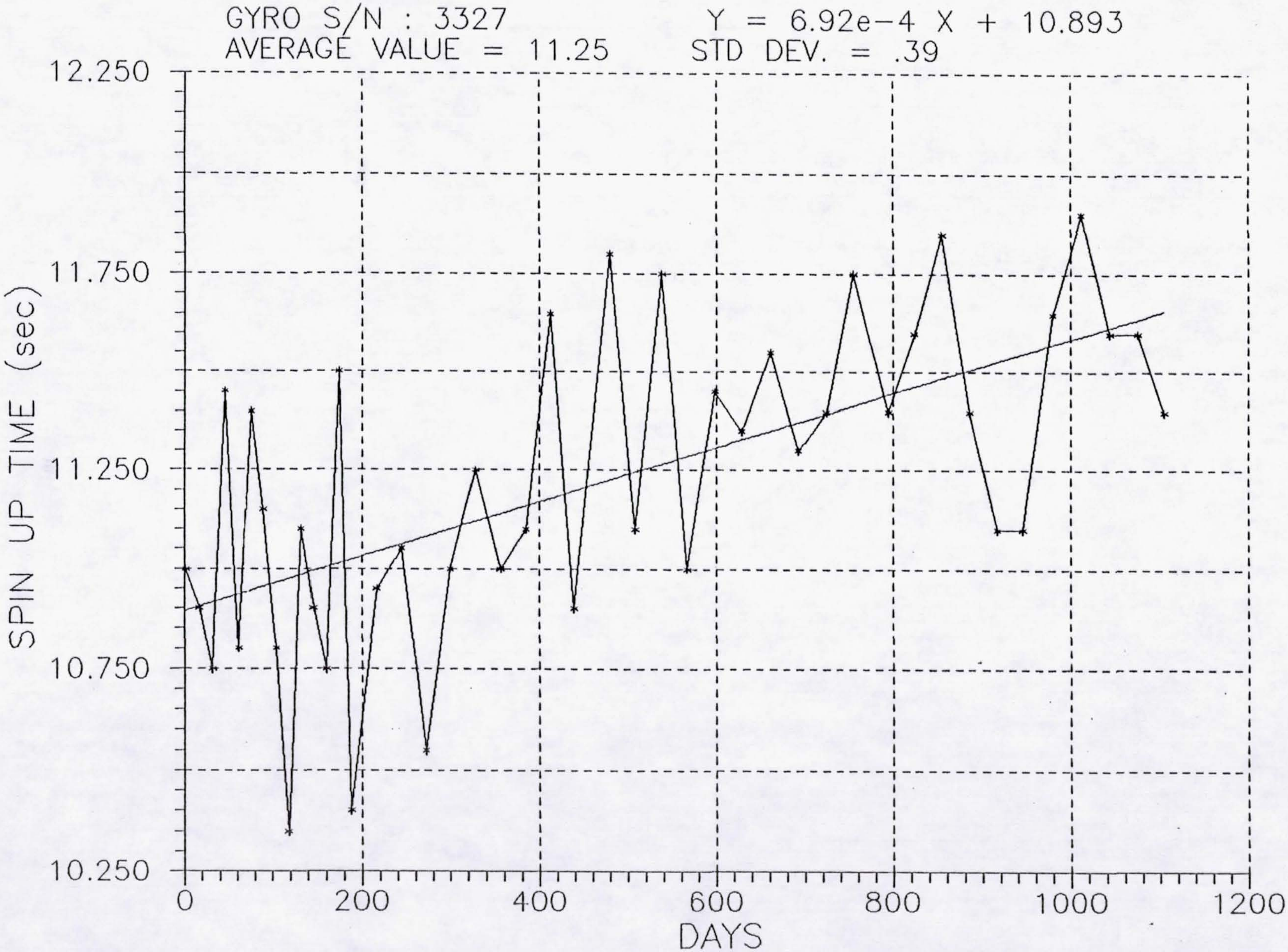
BY:3327LIF1
07/15/93
NOTE: BASELINE, TEST #2 & #5 are not used for AVGE & STANDARD DEVIATI

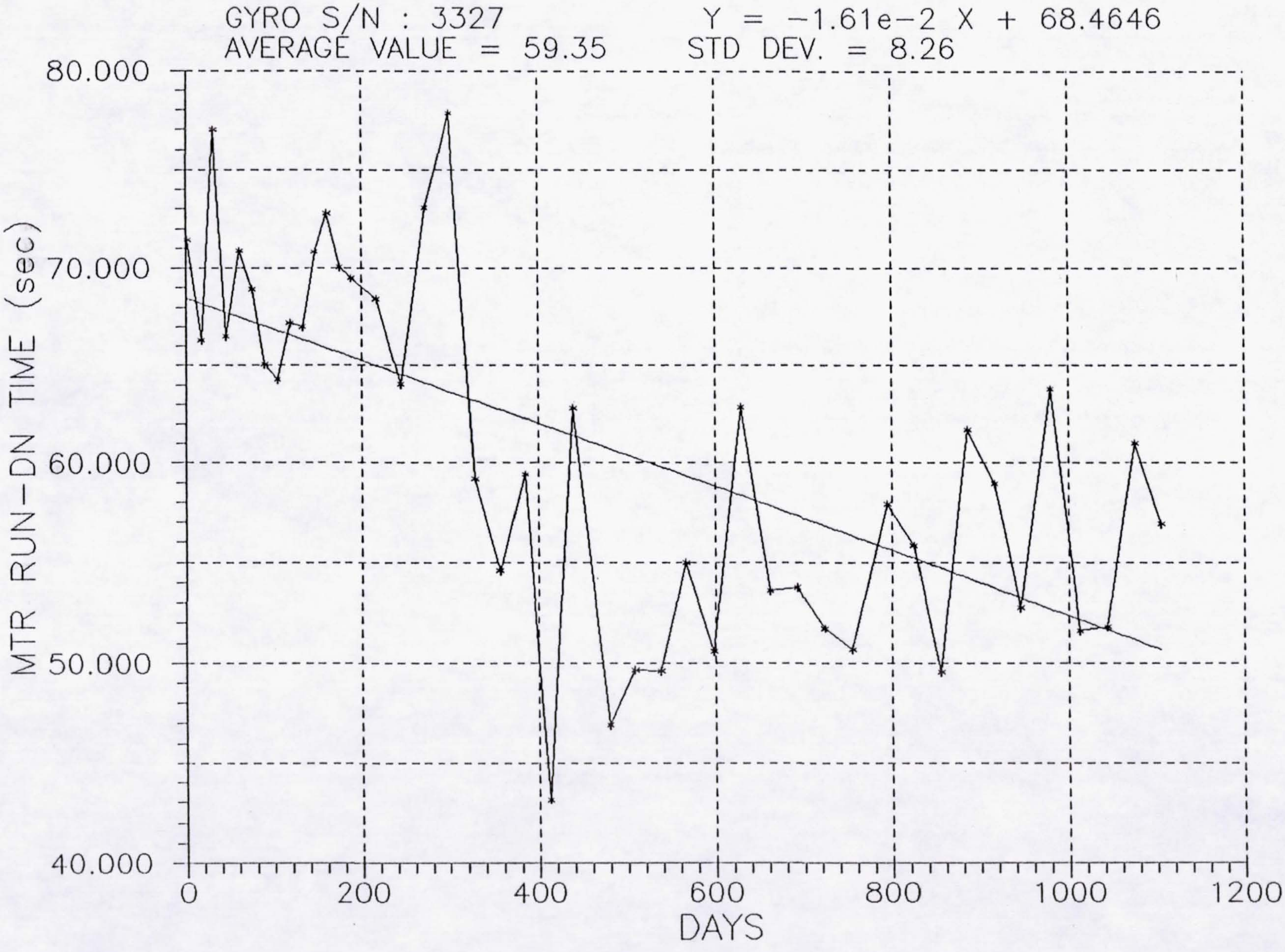
PARAGRAPH	PARAMETER	UNITS	NOMINAL PERFORMANCE	TEST NO: BASELINE MEASURED TEST DATE 12/19/92 TESTER MIKE N.	#2 MEASURED TEST DATE 01/04/93 TESTER MIKE N.	#3 MEASURED TEST DATE 01/18/93 TESTER LISA D.	#4 MEASURED TEST DA 02/01/9 TESTER LISA D.	#5 MEASURED TEST DATE 02/17/93 TESTER LISA D.	#6 MEASURED TEST DATE 03/03/93 TESTER LISA D.
3.2.1	RUN UP TIME	SECONDS	< 16	11.00	10.90	10.75	11.4	10.80	11.40
3.2.2	MTR START CURRENT	MILLI-AMPS	< 150	77.29	77.08	77.11	77.4	77.77	78.83
3.2.3	MTR RUN CURRENT	MILLI-AMPS	< 150	32.38	35.11	33.58	34.3	34.52	36.09
3.2.4	MTR RUN-ON TIME	SECONDS	> 20	71.44	66.29	77.00	66.50	70.87	68.91
3.2.5	SAH TUNED FREQ	HERTZ	397 - 403	398.5	398.4	398.4	398.4	398.5	398.5
3.2.6	SAV TUNED FREQ	HERTZ	393 - 401	396.1	396.0	396.0	396.0	396.1	396.1
3.2.7	TIME CONSTANT	SECONDS	> 15	17.9	17.8	17.8	18.3	18.3	18.1
3.2.8(A)	X PO OFFSET	ARC SECS	+/- 6	-0.5	-1.2	-2.4	-2.3	-2.2	-2.7
3.2.8(B)	Y PO OFFSET	ARC SECS	+/- 6	1.0	1.0	1.4	0.7	0.9	1.4
3.2.9(A)	X NULL QUAD	ARC SECS	+/- 20	2.19	2.29	2.39	1.90	0.40	1.72
3.2.9(B)	Y NULL QUAD	ARC SECS	+/- 20	0.51	0.38	0.54	0.26	1.22	0.18
3.2.10.1(A)	X TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2340	0.2330	0.2340	0.2342	0.2330	0.2338
3.2.10.1(B)	Y TORQUER SF	DEG/SEC/MA	> OR = 0.22	0.2390	0.2380	0.2390	0.2383	0.2382	0.2387
3.2.10.2(A)	X BIAS	DEG/HR	+/- 20	-4.235	-4.107	-4.068	-4.021	-3.980	-3.888
3.2.10.2(B)	Y BIAS	DEG/HR	+/- 20	-17.052	-17.114	-17.126	-17.197	-17.067	-17.339
3.2.10.3(A)	X DIRECT MASS UNB	DEG/HR/G	+/- 10	-4.374	-4.240	-4.196	-4.210	-4.258	-4.201
3.2.10.3(B)	Y DIRECT MASS UNB	DEG/HR/G	+/- 10	-4.328	-4.253	-4.227	-4.242	-4.288	-4.225
3.2.10.4(A)	X QUAD MASS UNBAL	DEG/HR/G	+/- 10	-0.494	-0.581	-0.620	-0.672	-0.632	-0.647
3.2.10.4(B)	Y QUAD MASS UNBAL	DEG/HR/G	+/- 10	0.456	0.502	0.535	0.516	0.518	0.557

* NOTE: Test #5 was performed using the wrong test cube & dreamo electronics.

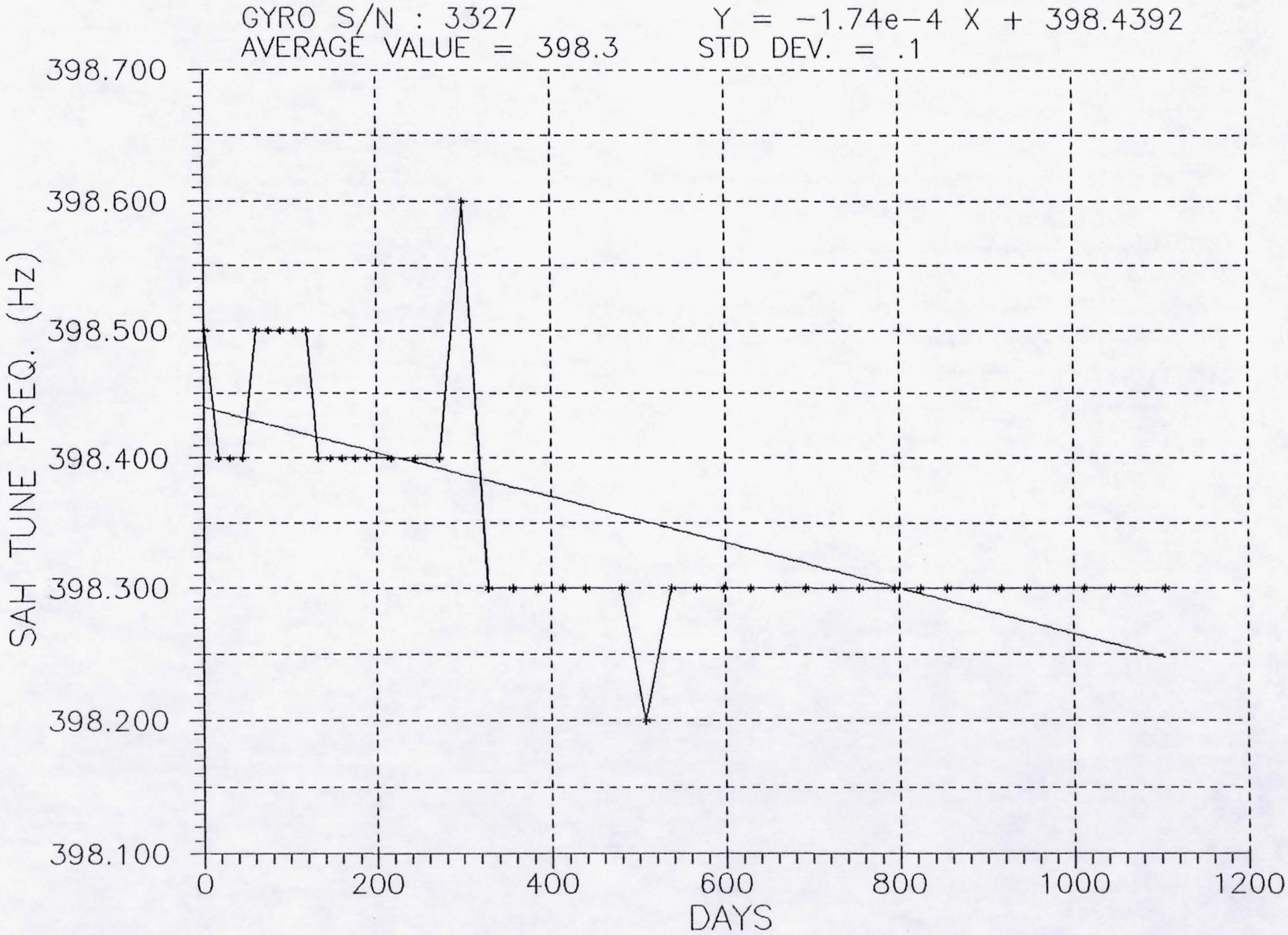

GYRO S/N : 3327
AVERAGE VALUE = 78.38
Y = −1.93e−4 X + 78.3658
STD DEV. = 2.04
MTR START CURRENT (mA)
90.000
85.000
80.000
75.000
0
200
400
600
800
1000
1200
DAYS

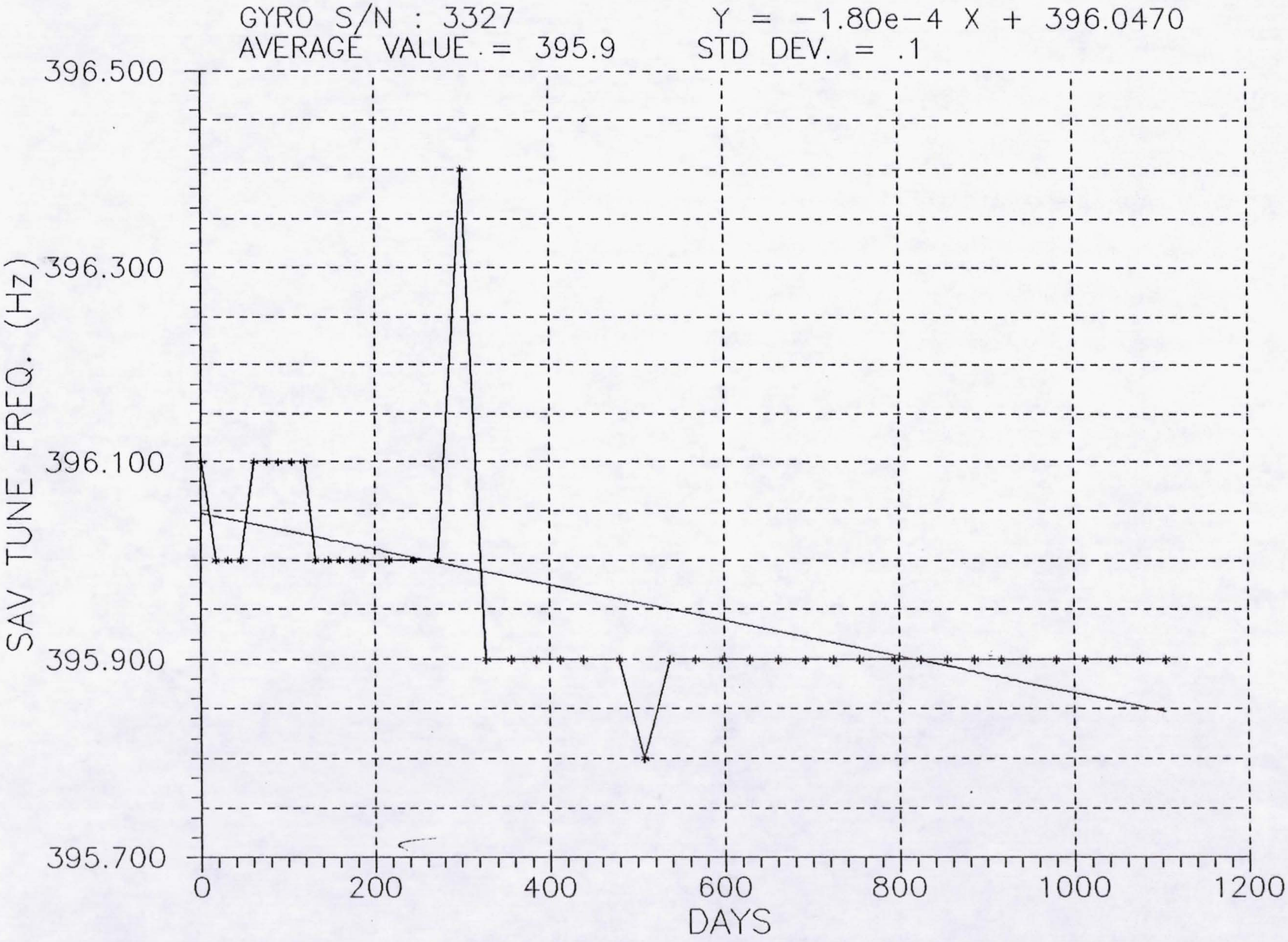

GYRO S/N : 3327
AVERAGE VALUE = 37.64
Y = 3.678e-3 X + 35.4429
STD DEV. = 2.37
MTR RUN CURRENT (mA)
44.000
40.000
36.000
32.000
0
200
400
600
800
1000
1200
DAYS

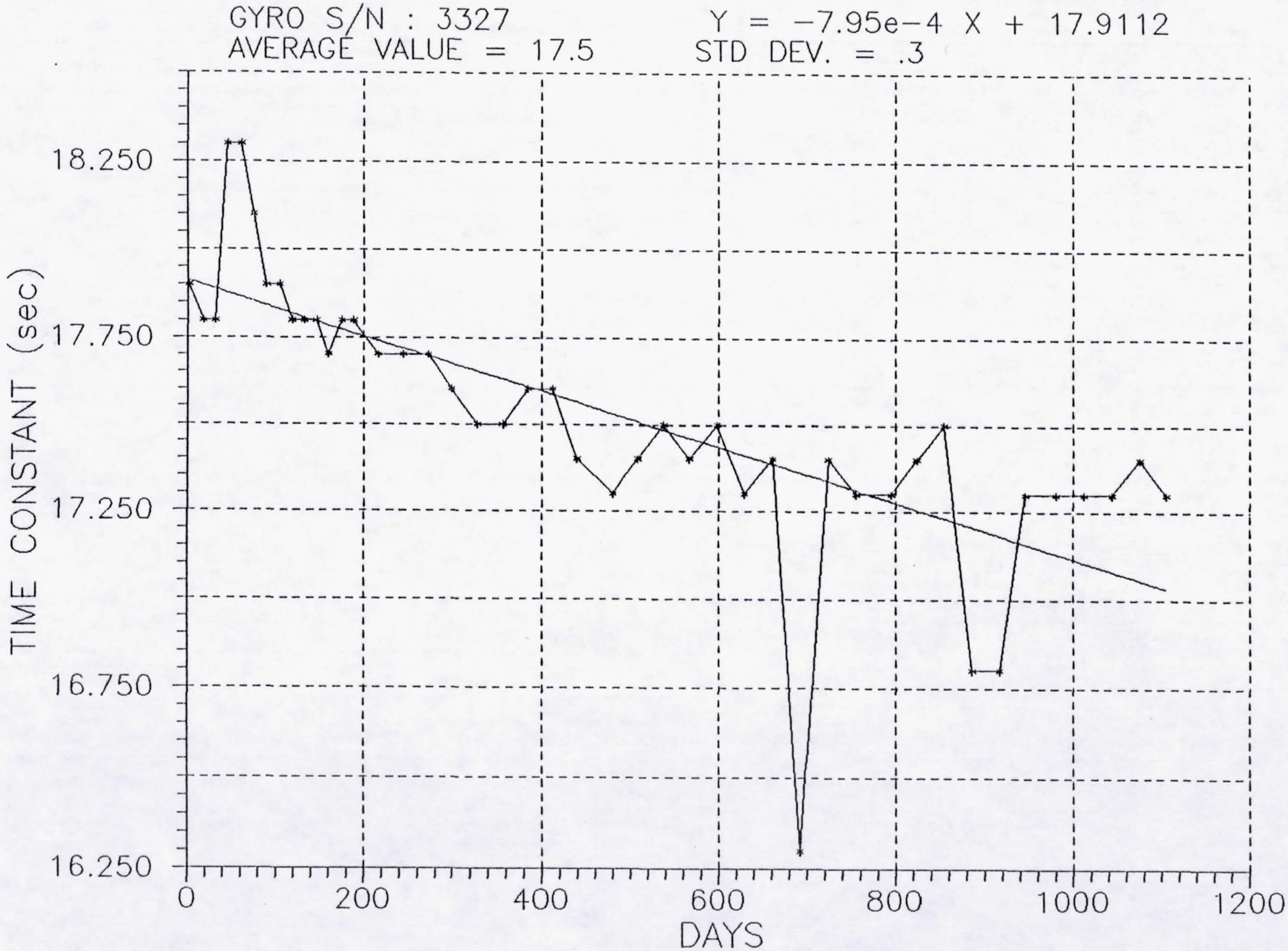

GYRO S/N : 3327
Y = 6.92e-4 X + 10.893
AVERAGE VALUE = 11.25
STD DEV. = .39
12.250
11.750
11.250
10.750
10.250
SPIN UP TIME (sec)
0
200
400
600
800
1000
1200
DAYS

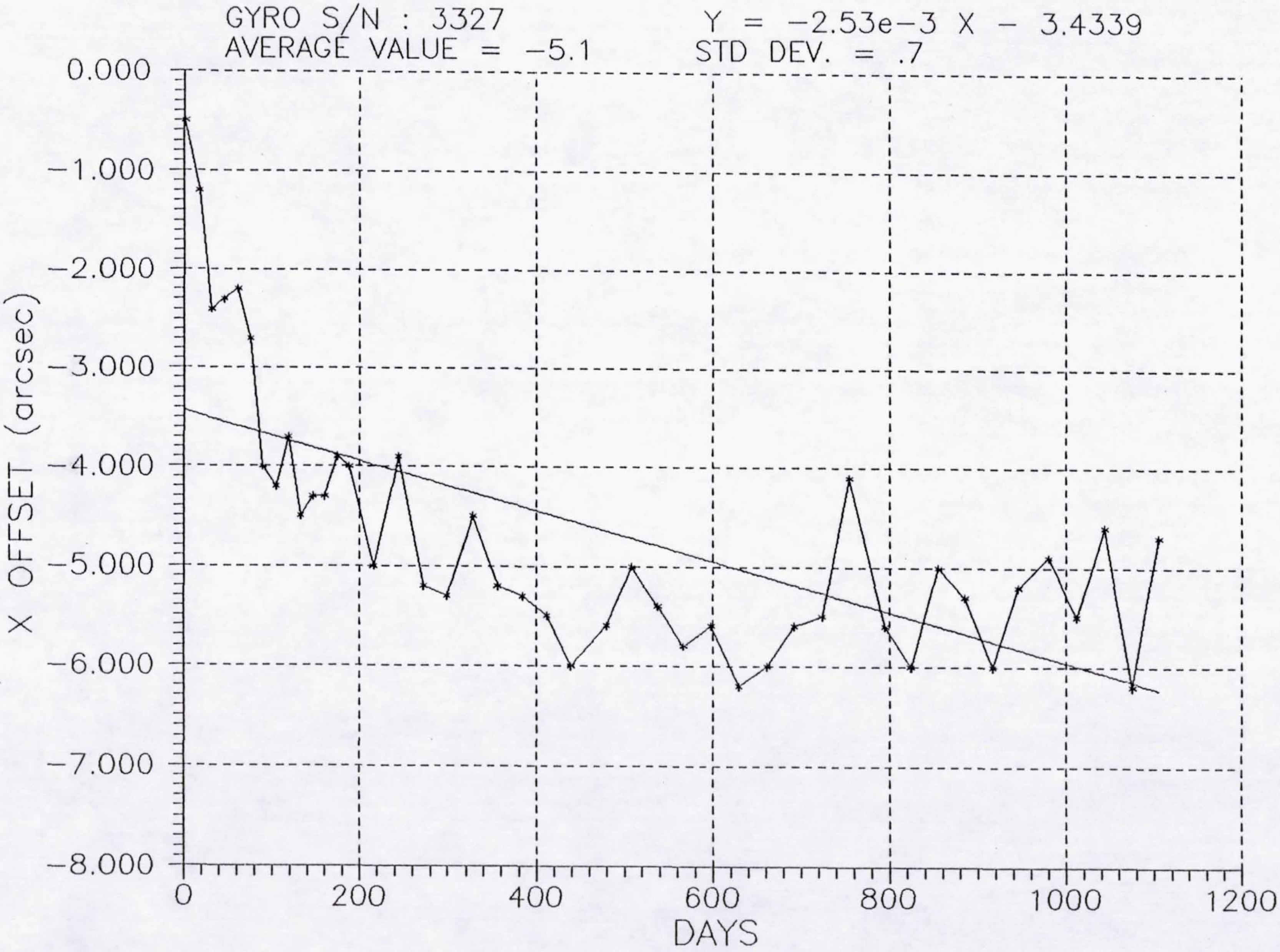

GYRO S/N : 3327
AVERAGE VALUE = 59.35
Y = -1.61e-2 X + 68.4646
STD DEV. = 8.26
80.000
70.000
60.000
50.000
40.000
MTR RUN-DN TIME (sec)
0
200
400
600
800
1000
1200
DAYS

47


GYRO S/N : 3327
Y = −1.74e−4 X + 398.4392
AVERAGE VALUE = 398.3
STD DEV. = .1
SAH TUNE FREQ. (Hz)
398.700
398.600
398.500
398.400
398.300
398.200
398.100
0
200
400
600
800
1000
1200
DAYS

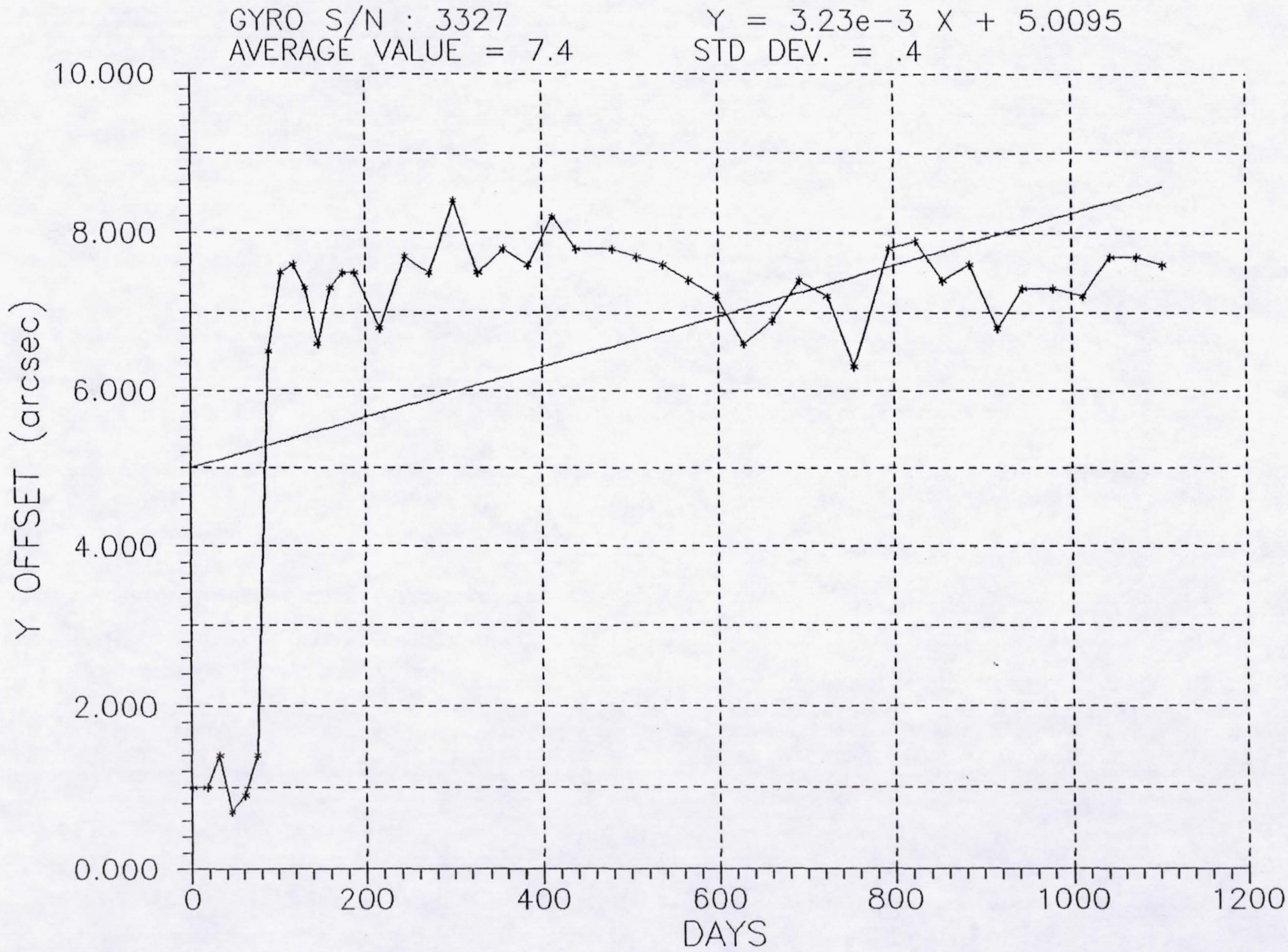

GYRO S/N : 3327
Y = −1.80e−4 X + 396.0470
AVERAGE VALUE = 395.9
STD DEV. = .1
SAV TUNE FREQ. (Hz)
396.500
396.300
396.100
395.900
395.700
0
200
400
600
800
1000
1200
DAYS

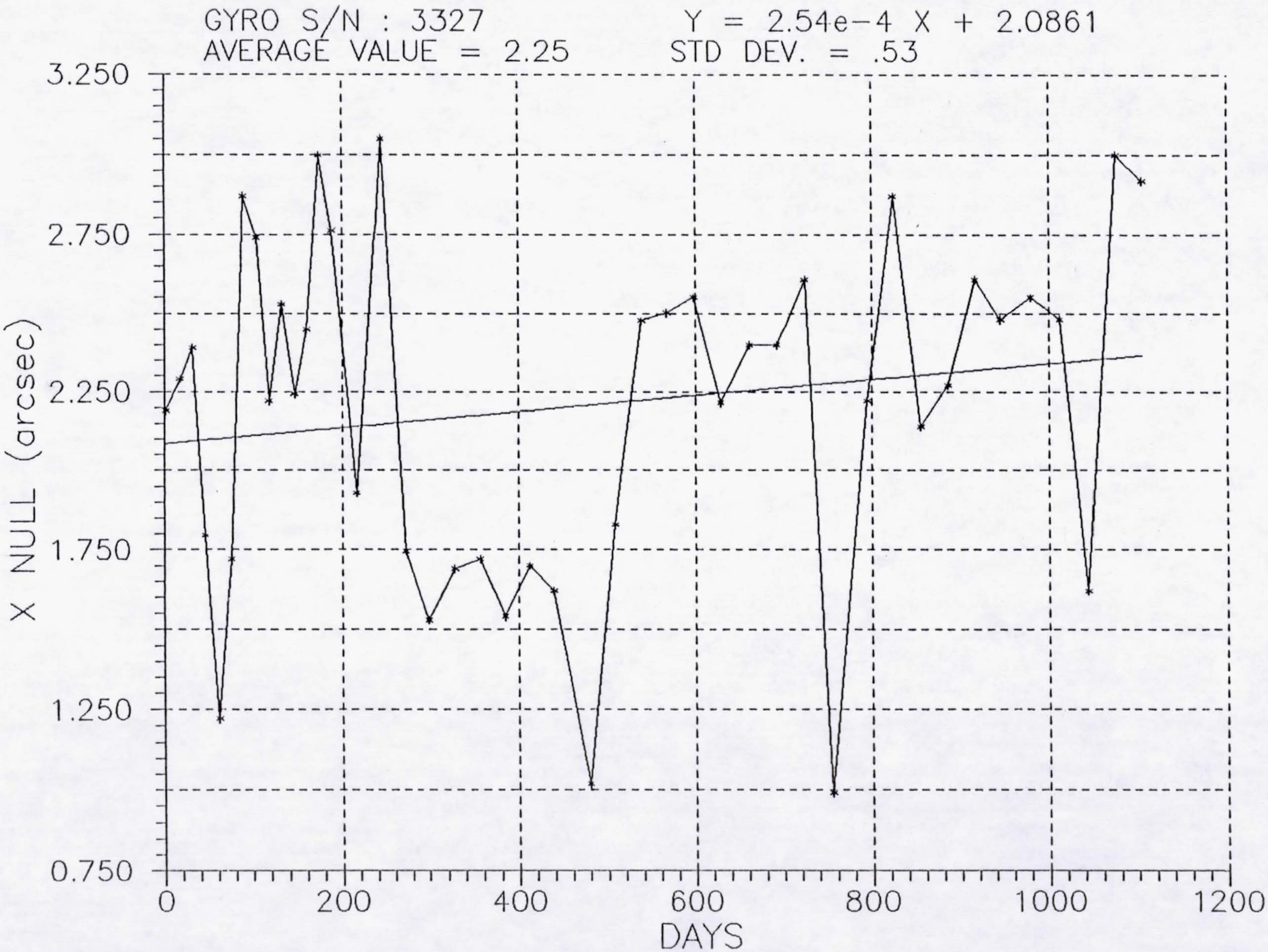

GYRO S/N : 3327
AVERAGE VALUE = 17.5
Y = −7.95e−4 X + 17.9112
STD DEV. = .3
TIME CONSTANT (sec)
18.250
17.750
17.250
16.750
16.250
0
200
400
600
800
1000
1200
DAYS



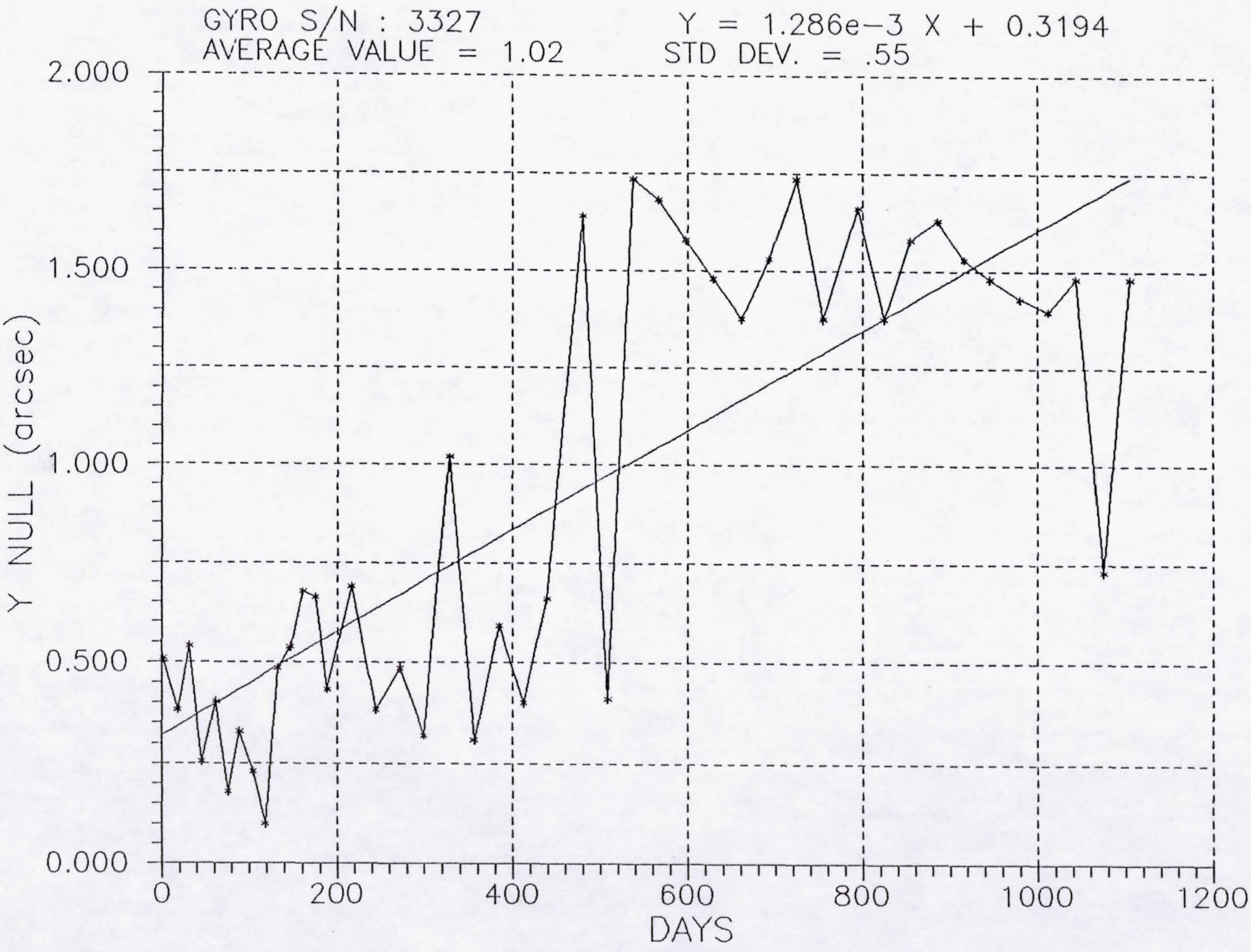
GYRO S/N : 3327
AVERAGE VALUE = -5.1
Y = -2.53e-3 X - 3.4339
STD DEV. = .7
0.000
-1.000
-2.000
-3.000
-4.000
-5.000
-6.000
-7.000
-8.000
X OFFSET (arcsec)
0
200
400
600
800
1000
1200
DAYS

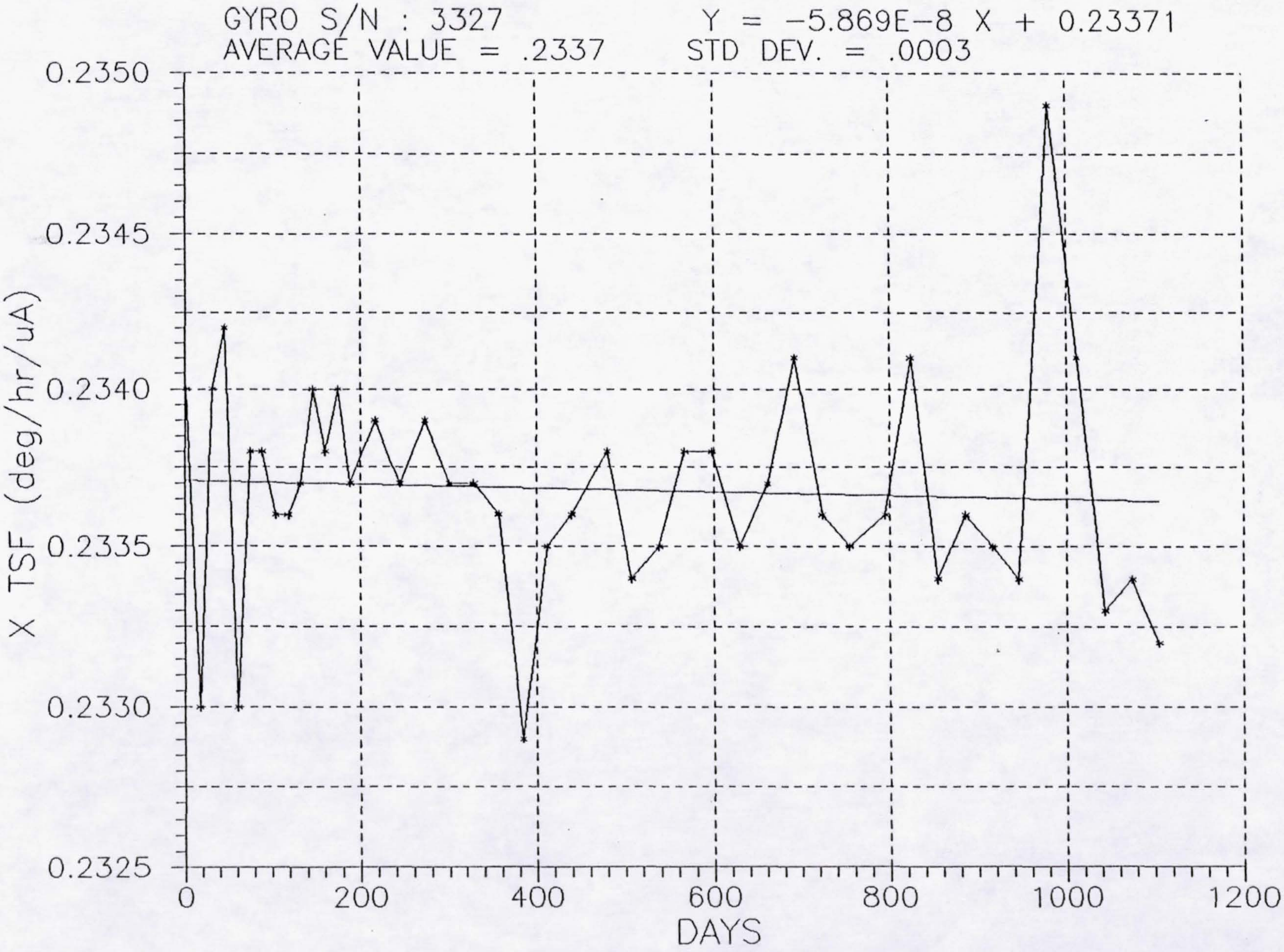
51

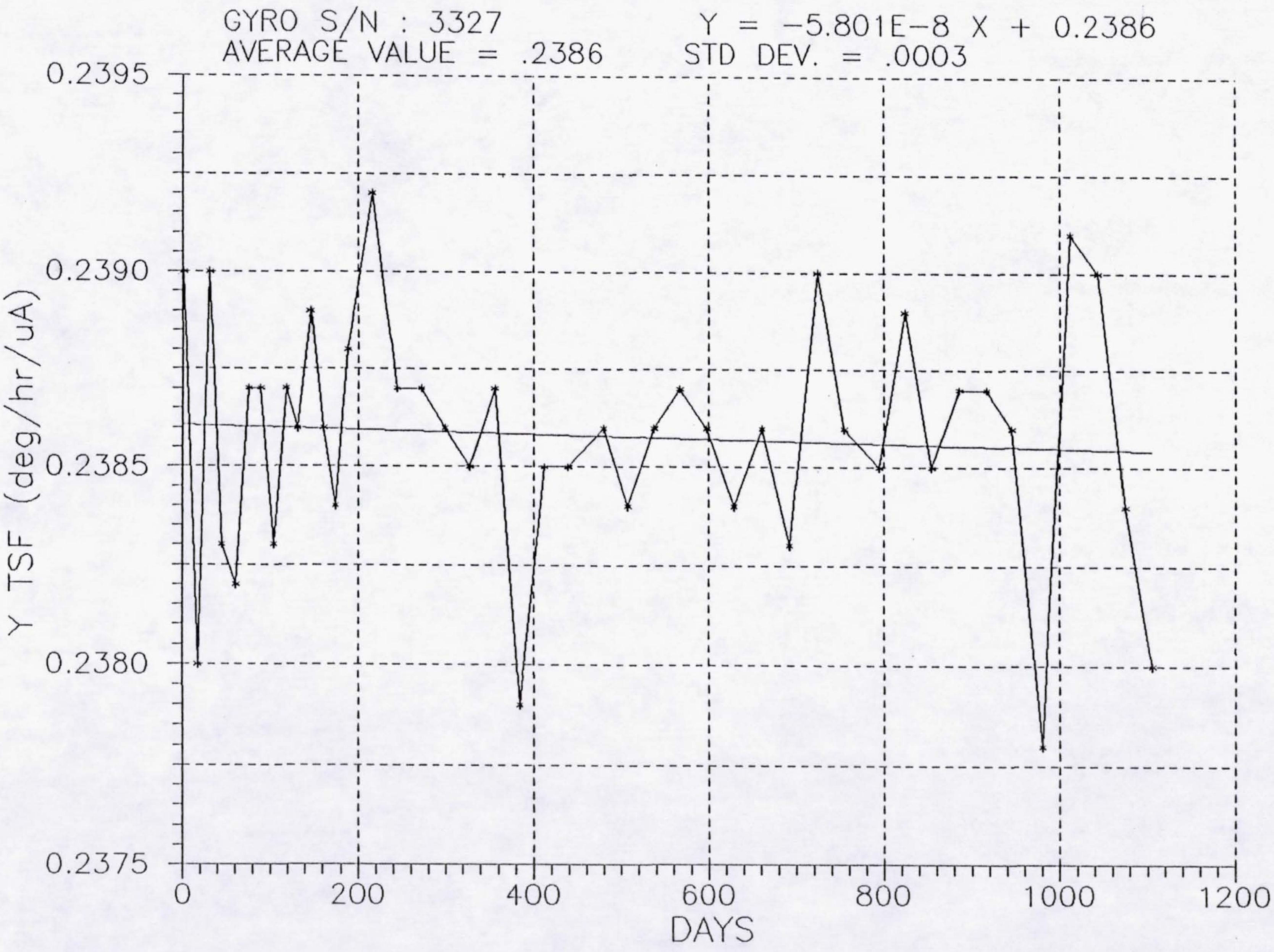

GYRO S/N : 3327
Y = 3.23e-3 X + 5.0095
AVERAGE VALUE = 7.4
STD DEV. = .4
10.000
8.000
6.000
4.000
2.000
0.000
Y OFFSET (arcsec)
0
200
400
600
800
1000
1200
DAYS

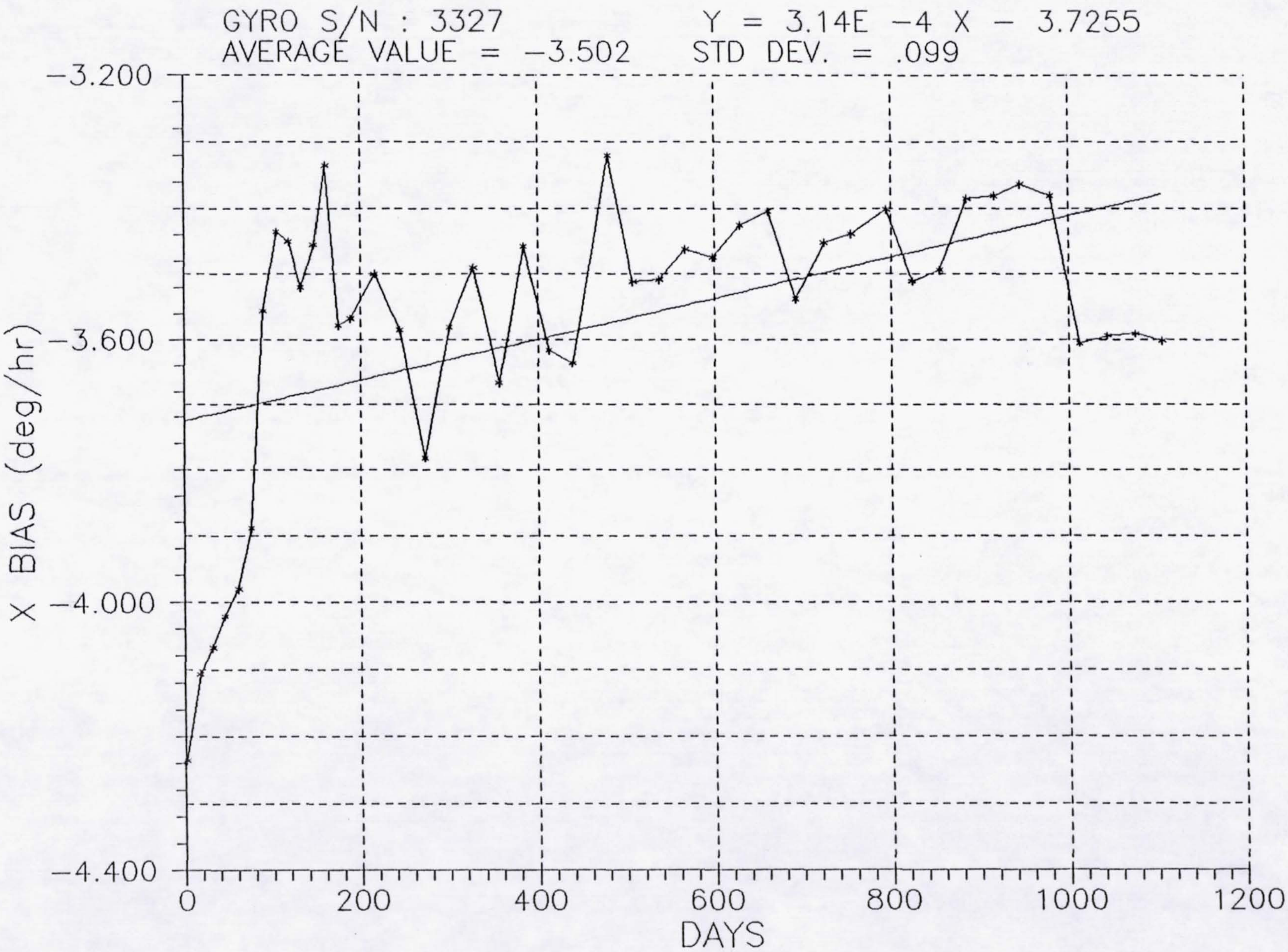

GYRO S/N : 3327
AVERAGE VALUE = 2.25
Y = 2.54e-4 X + 2.0861
STD DEV. = .53
3.250
2.750
2.250
1.750
1.250
0.750
X NULL (arcsec)
0
200
400
600
800
1000
1200
DAYS

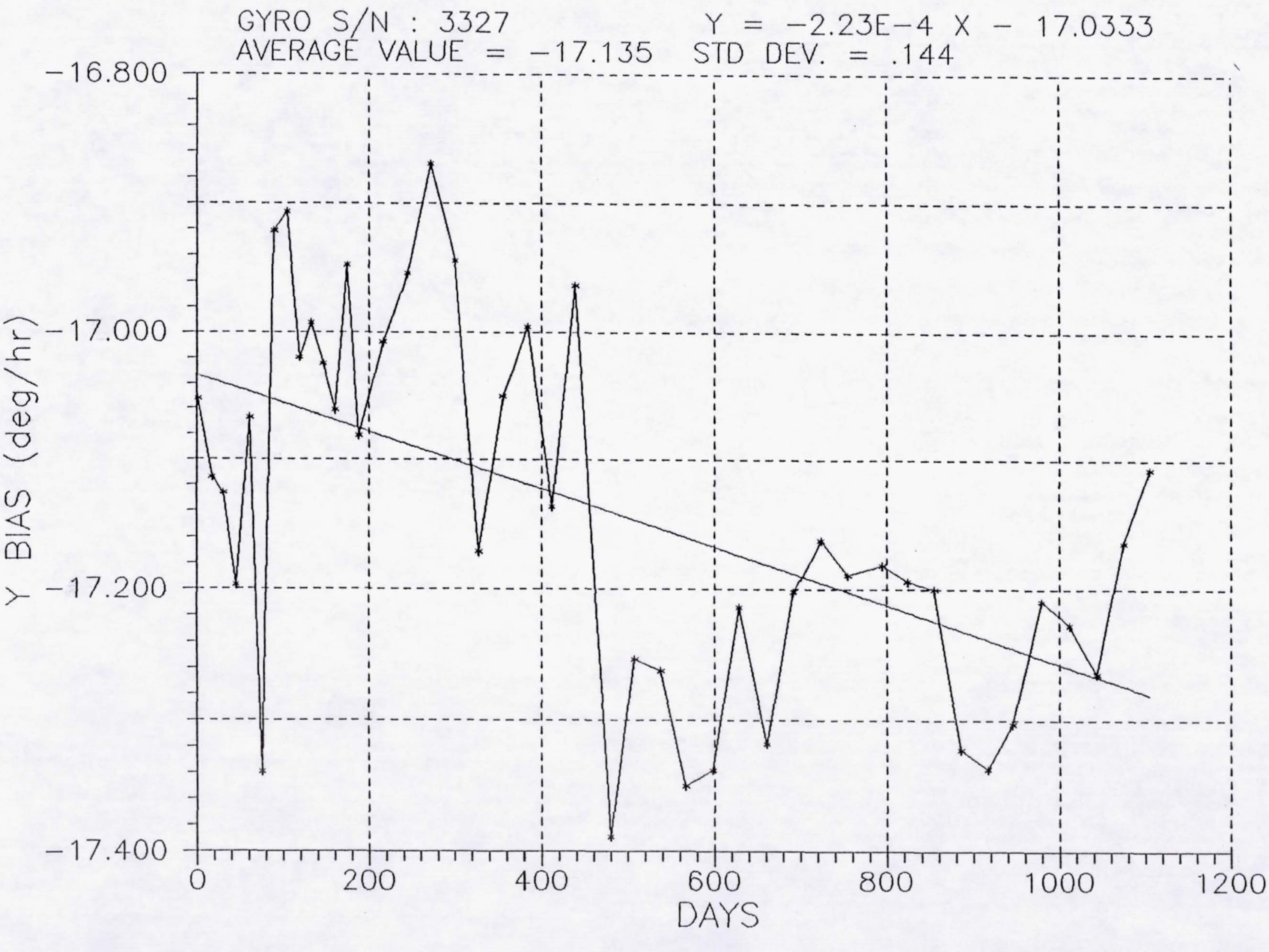
53

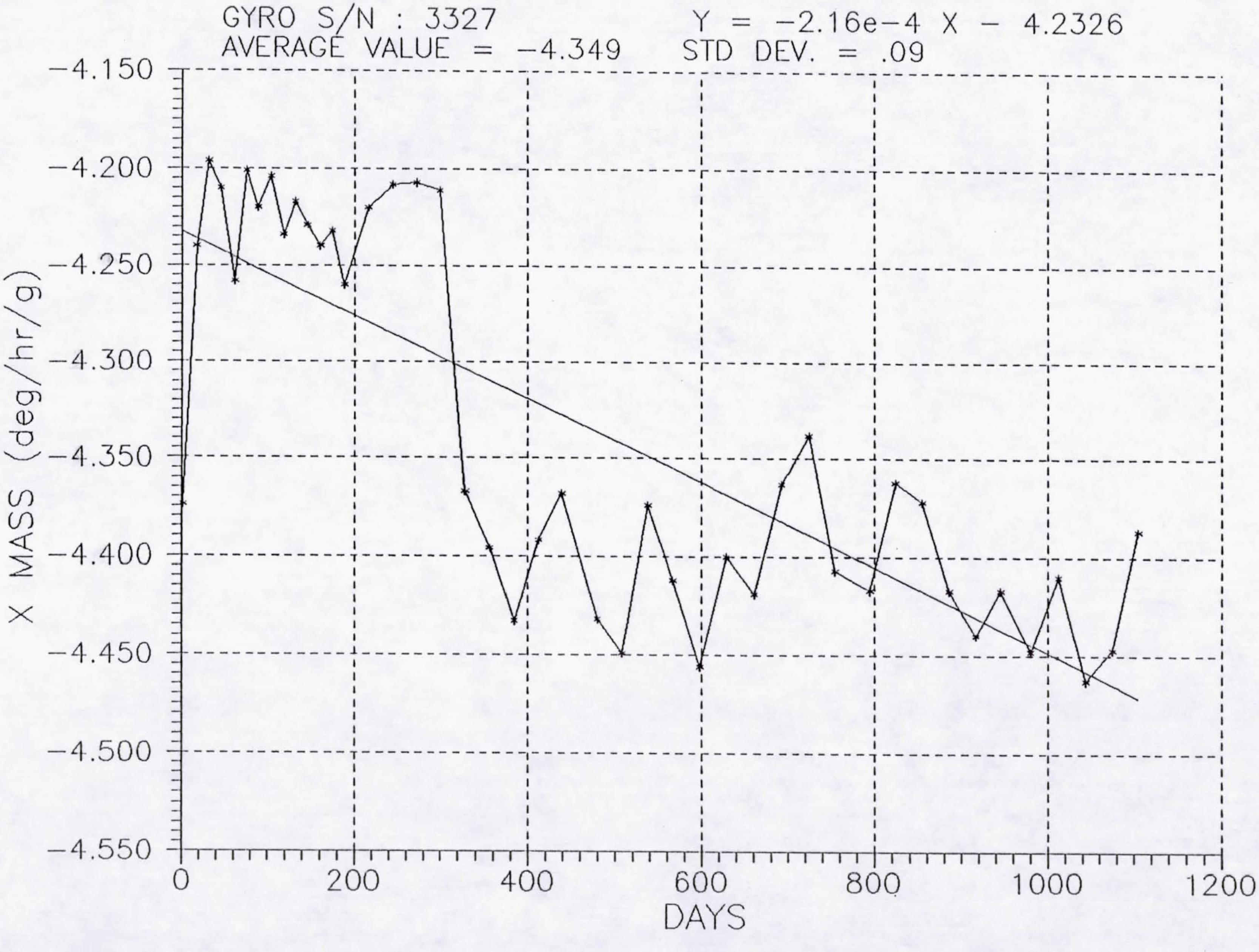

GYRO S/N : 3327
AVERAGE VALUE = 1.02
Y = 1.286e-3 X + 0.3194
STD DEV. = .55
Y NULL (arcsec)
2.000
1.500
1.000
0.500
0.000
0
200
400
600
800
1000
1200
DAYS

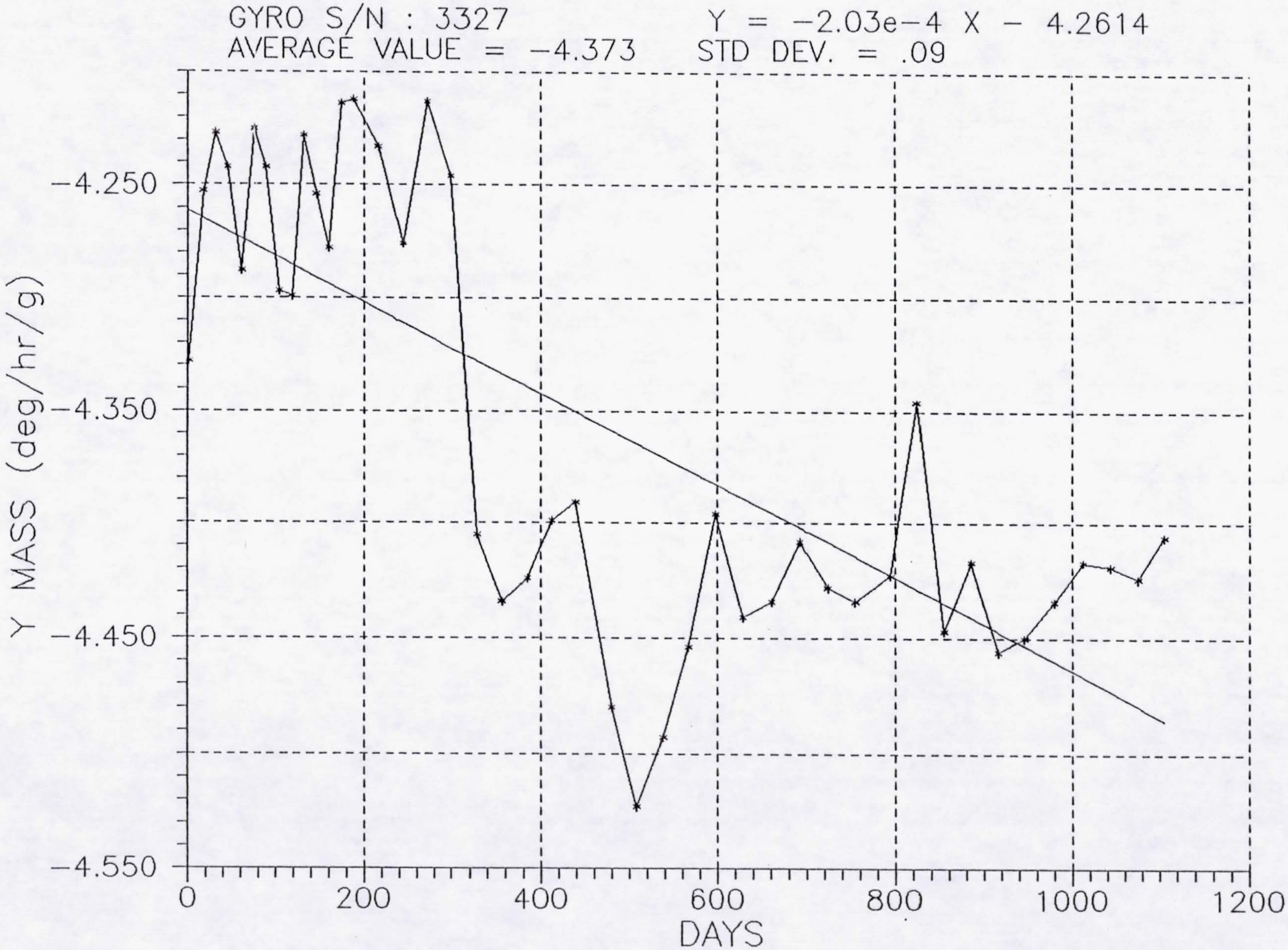

GYRO S/N : 3327
Y = −5.869E−8 X + 0.23371
AVERAGE VALUE = .2337
STD DEV. = .0003
X TSF (deg/hr/uA)
0.2350
0.2345
0.2340
0.2335
0.2330
0.2325
0
200
400
600
800
1000
1200
DAYS

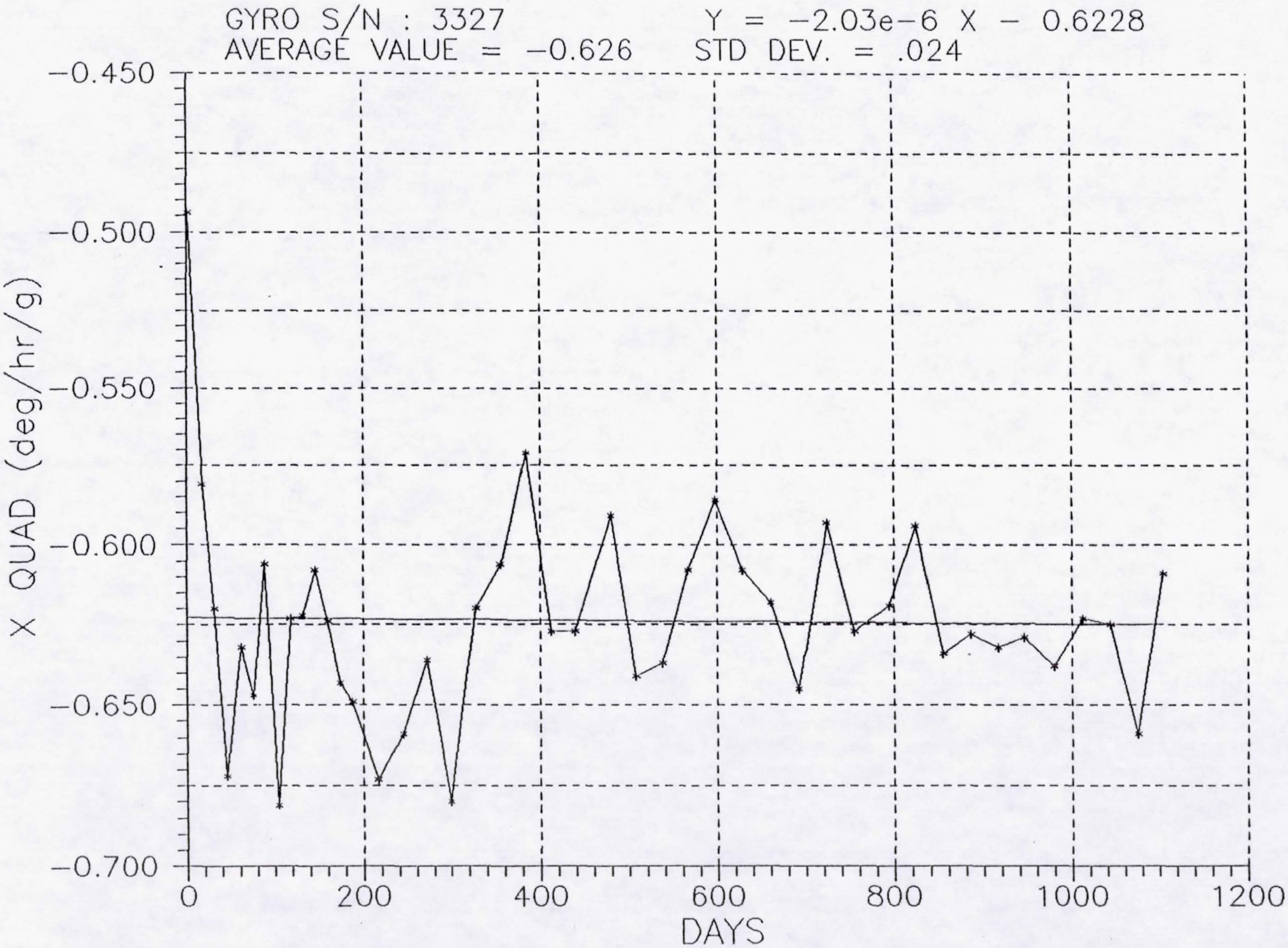

GYRO S/N : 3327
AVERAGE VALUE = .2386
Y = −5.801E−8 X + 0.2386
STD DEV. = .0003
0.2395
0.2390
0.2385
0.2380
0.2375
Y TSF (deg/hr/uA)
0
200
400
600
800
1000
1200
DAYS

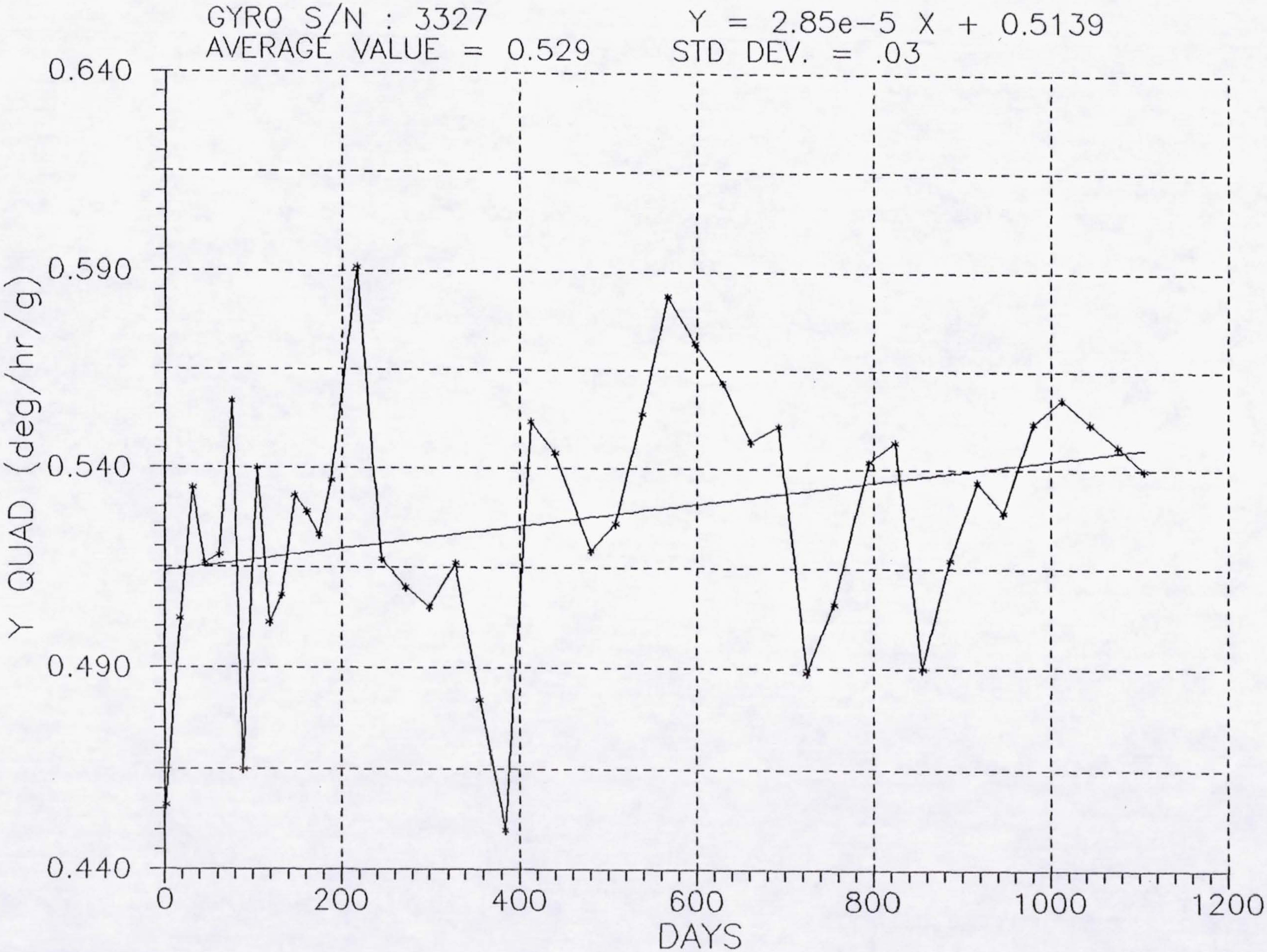

GYRO S/N : 3327
Y = 3.14E -4 X - 3.7255
AVERAGE VALUE = -3.502
STD DEV. = .099
-3.200
-3.600
-4.000
-4.400
X BIAS (deg/hr)
0
200
400
600
800
1000
1200
DAYS

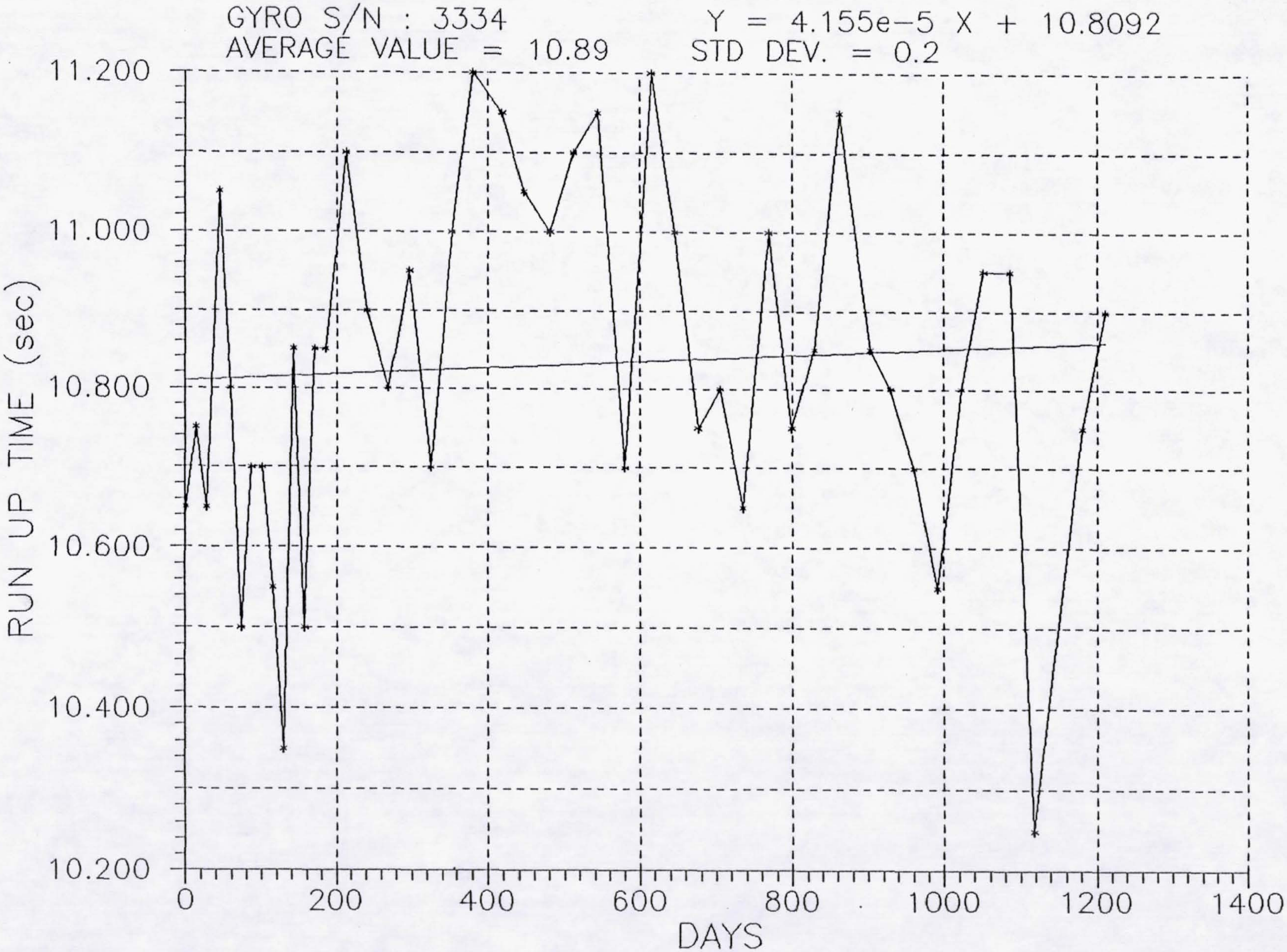

GYRO S/N : 3327
Y = −2.23E−4 X − 17.0333
AVERAGE VALUE = −17.135
STD DEV. = .144
−16.800
−17.000
−17.200
−17.400
Y BIAS (deg/hr)
0
200
400
600
800
1000
1200
DAYS


GYRO S/N : 3327
AVERAGE VALUE = -4.349
Y = -2.16e-4 X - 4.2326
STD DEV. = .09
X MASS (deg/hr/g)
-4.150
-4.200
-4.250
-4.300
-4.350
-4.400
-4.450
-4.500
-4.550
0
200
400
600
800
1000
1200
DAYS

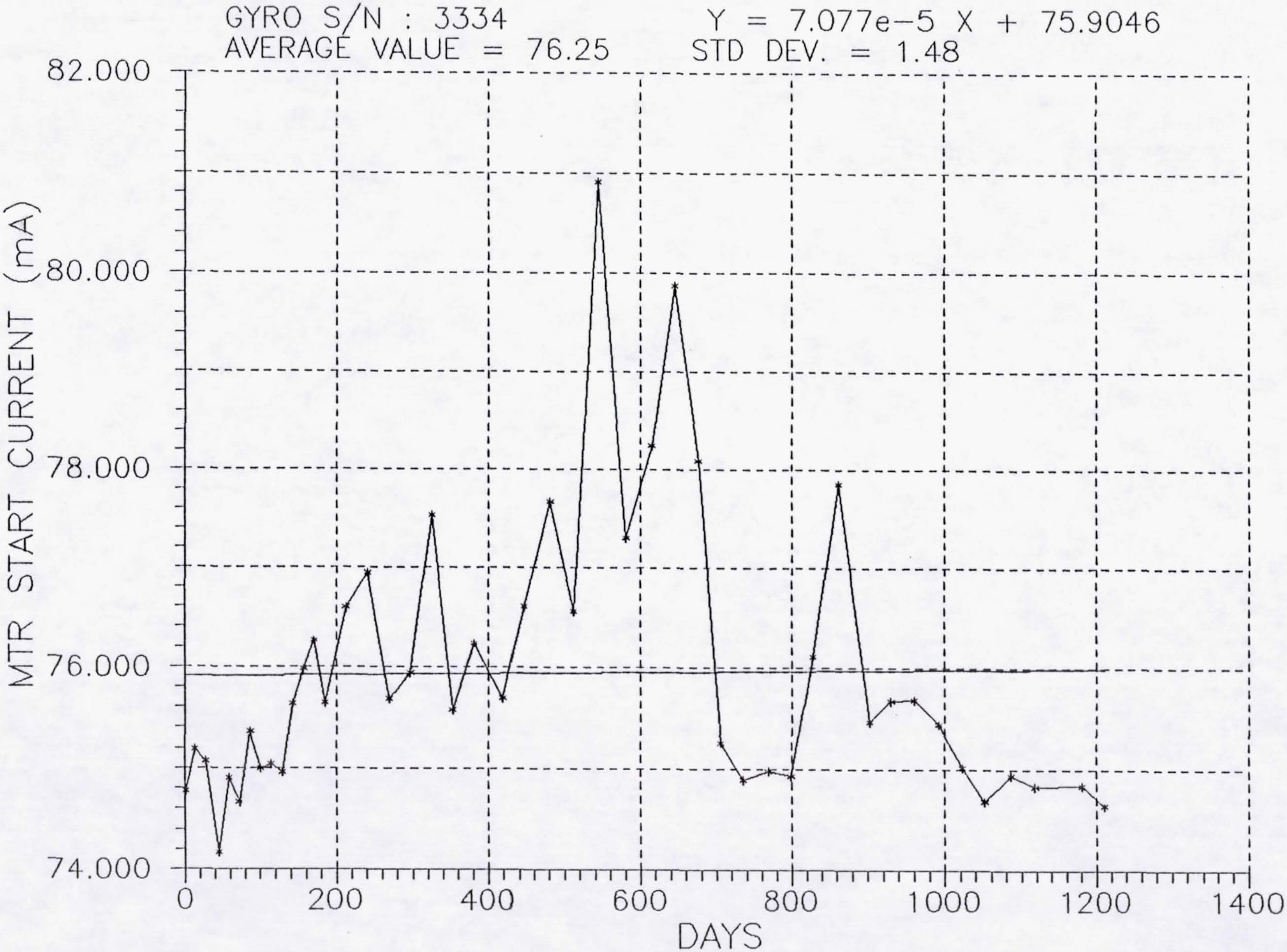

GYRO S/N : 3327
AVERAGE VALUE = -4.373
Y = -2.03e-4 X - 4.2614
STD DEV. = .09
-4.250
-4.350
-4.450
-4.550
Y MASS (deg/hr/g)
0
200
400
600
800
1000
1200
DAYS


GYRO S/N : 3327
Y = −2.03e−6 X − 0.6228
AVERAGE VALUE = −0.626
STD DEV. = .024
−0.450
−0.500
−0.550
−0.600
−0.650
−0.700
X QUAD (deg/hr/g)
0
200
400
600
800
1000
1200
DAYS


GYRO S/N : 3327
AVERAGE VALUE = 0.529
Y = 2.85e-5 X + 0.5139
STD DEV. = .03
0.640
0.590
0.540
0.490
0.440
Y QUAD (deg/hr/g)
0
200
400
600
800
1000
1200
DAYS

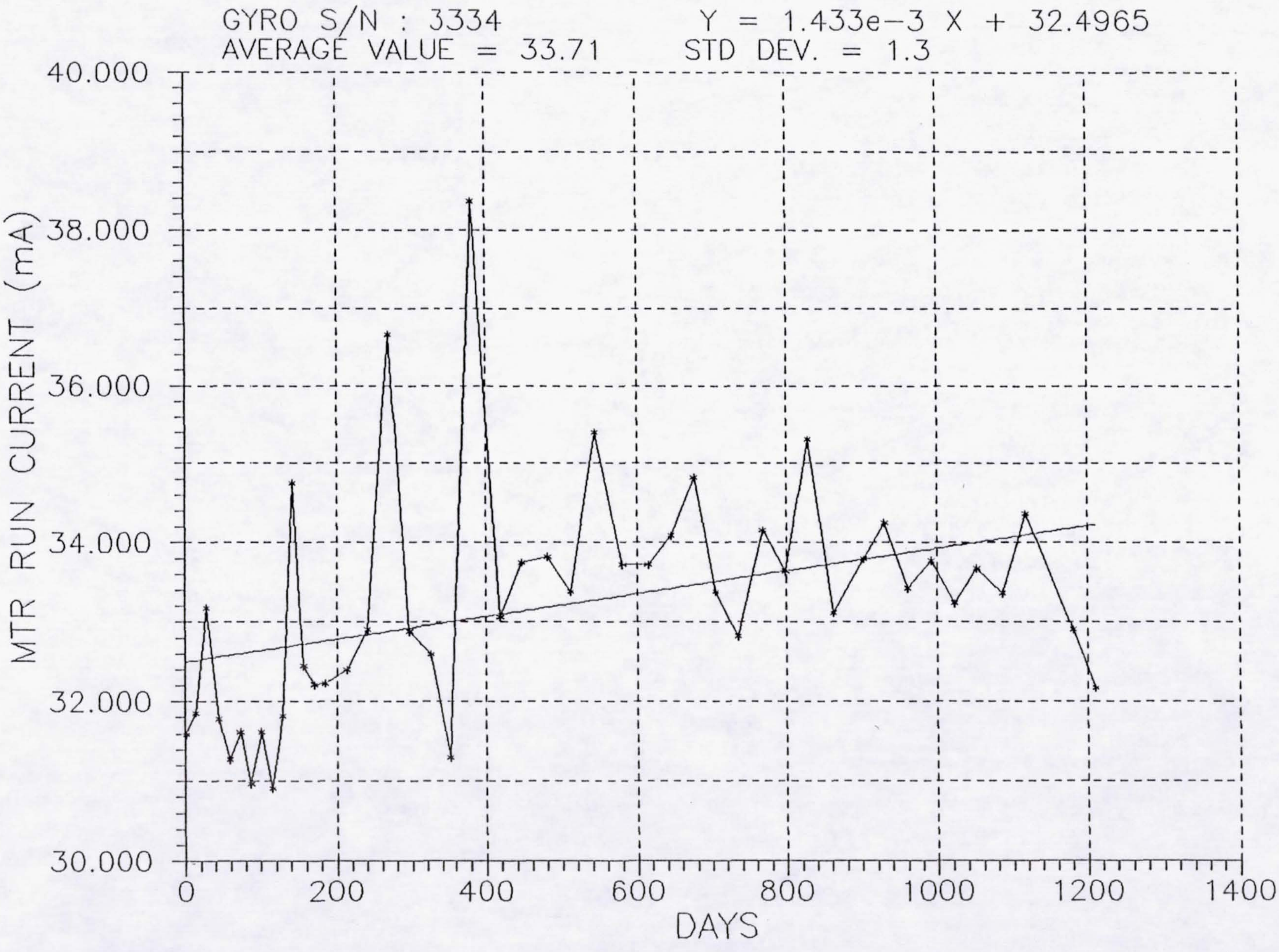


GYRO S/N : 3334
Y = 4.155e-5 X + 10.8092
AVERAGE VALUE = 10.89
STD DEV. = 0.2
RUN UP TIME (sec)
11.200
11.000
10.800
10.600
10.400
10.200
0
200
400
600
800
1000
1200
1400
DAYS

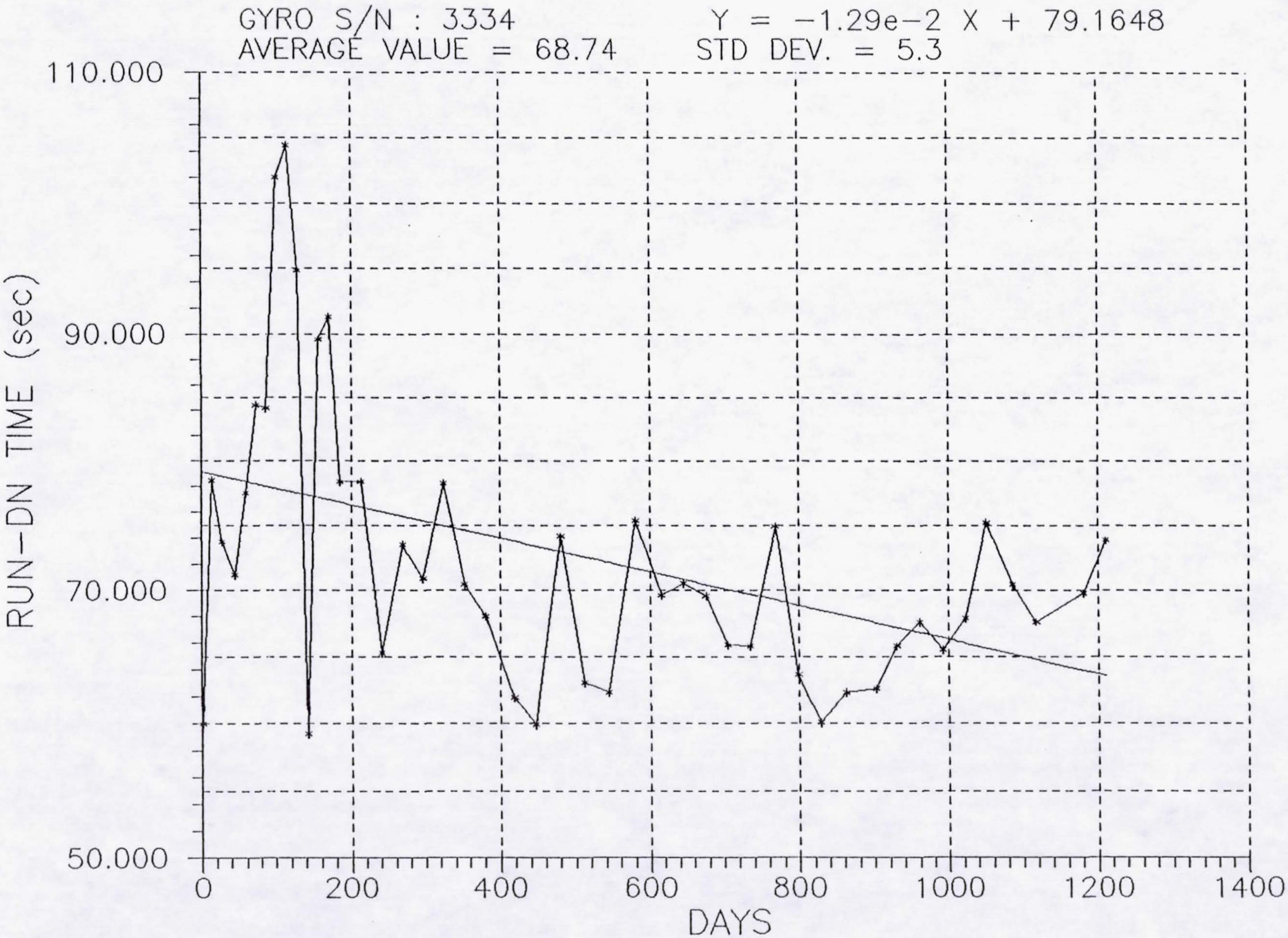


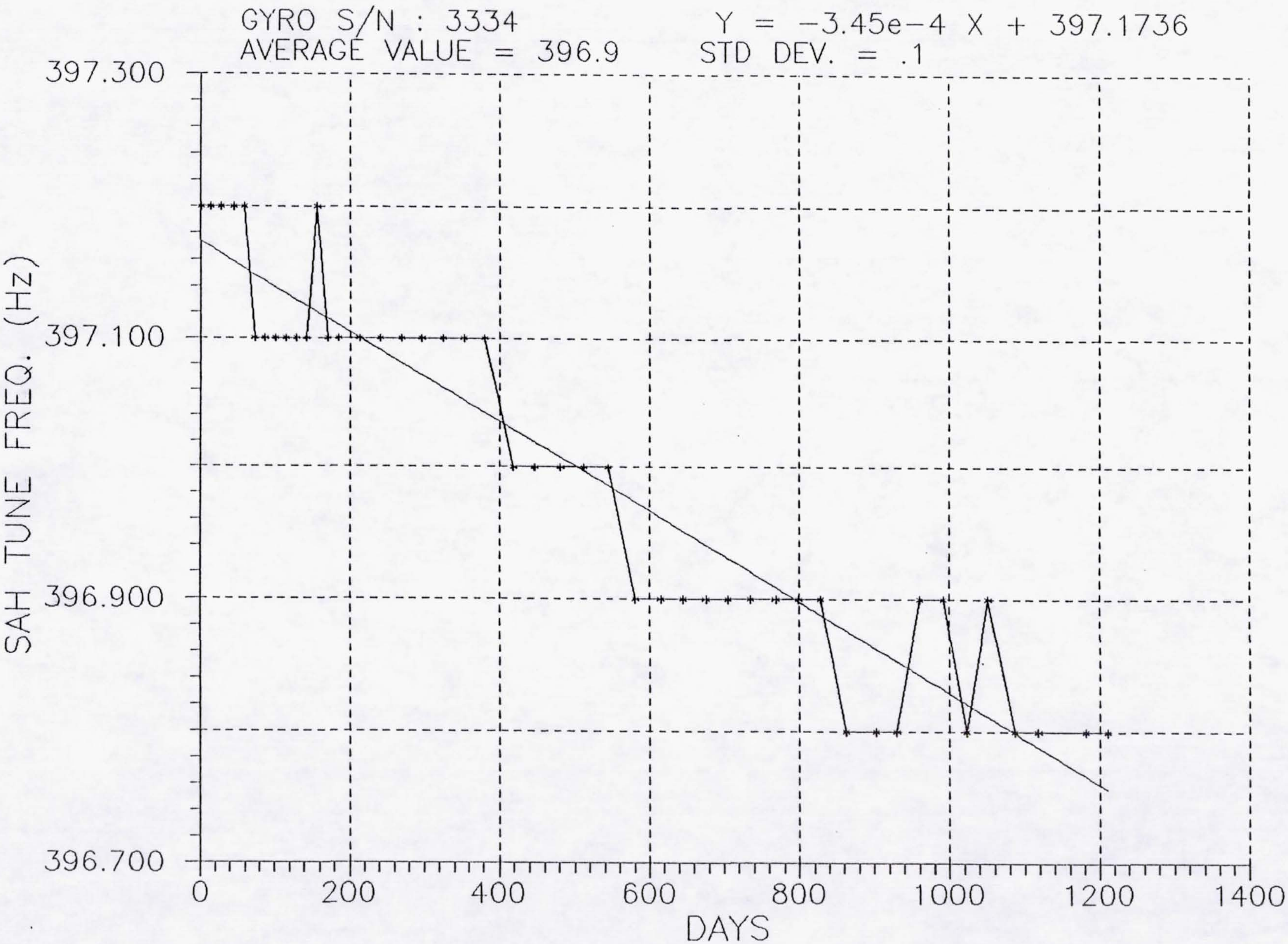
GYRO S/N : 3334
Y = 7.077e-5 X + 75.9046
AVERAGE VALUE = 76.25
STD DEV. = 1.48
MTR START CURRENT (mA)
82.000
80.000
78.000
76.000
74.000
0
200
400
600
800
1000
1200
1400
DAYS

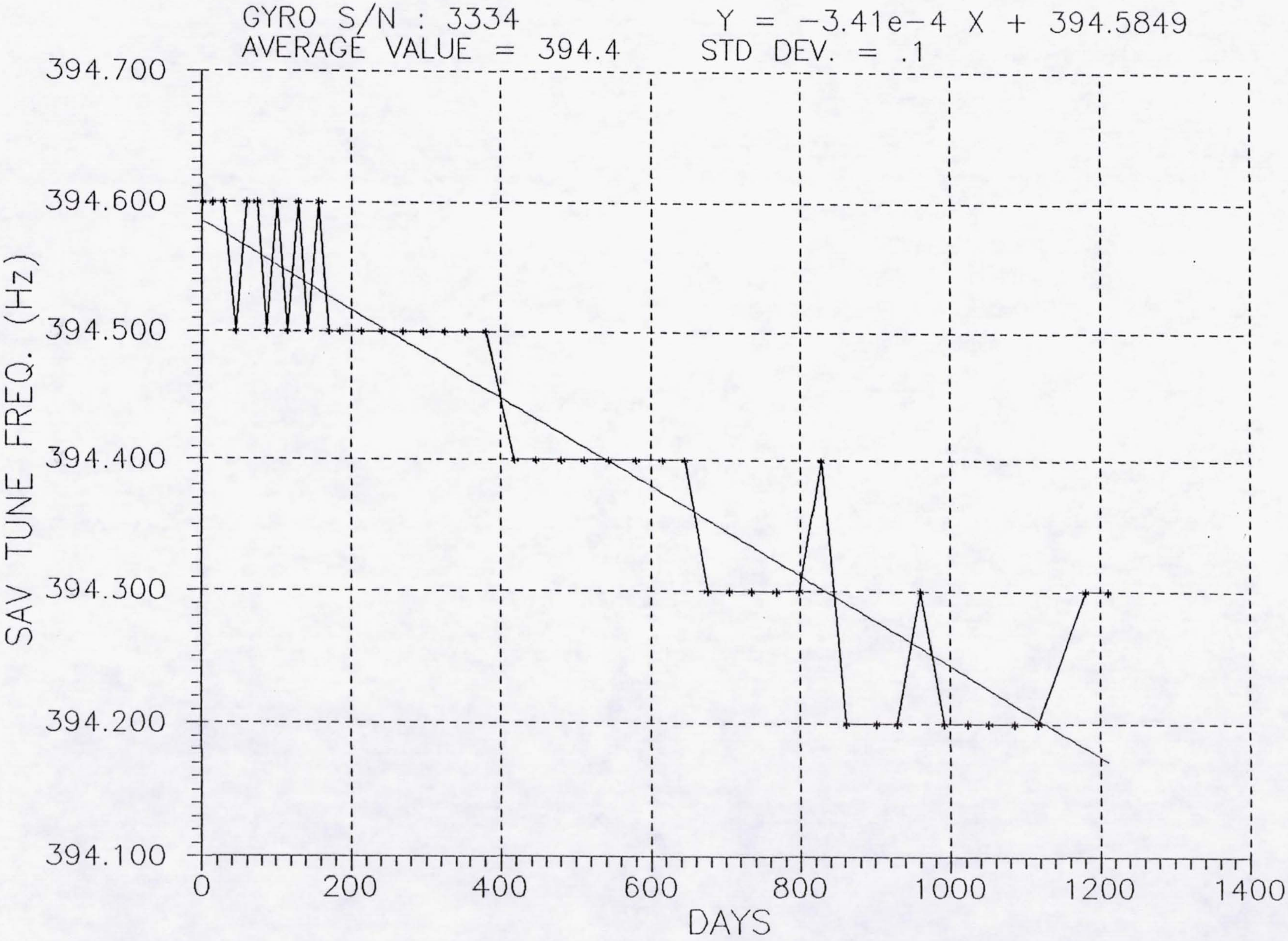
64

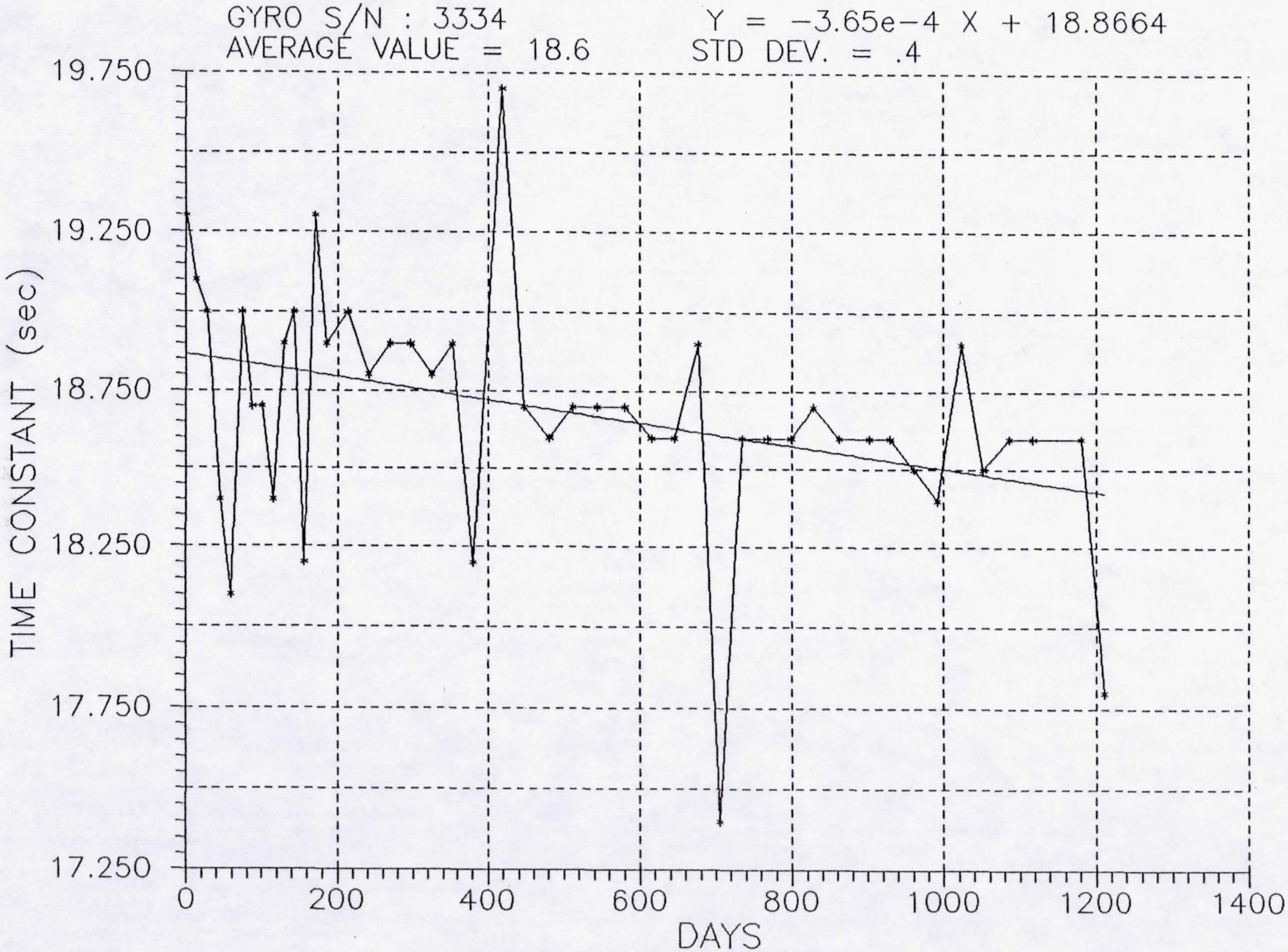


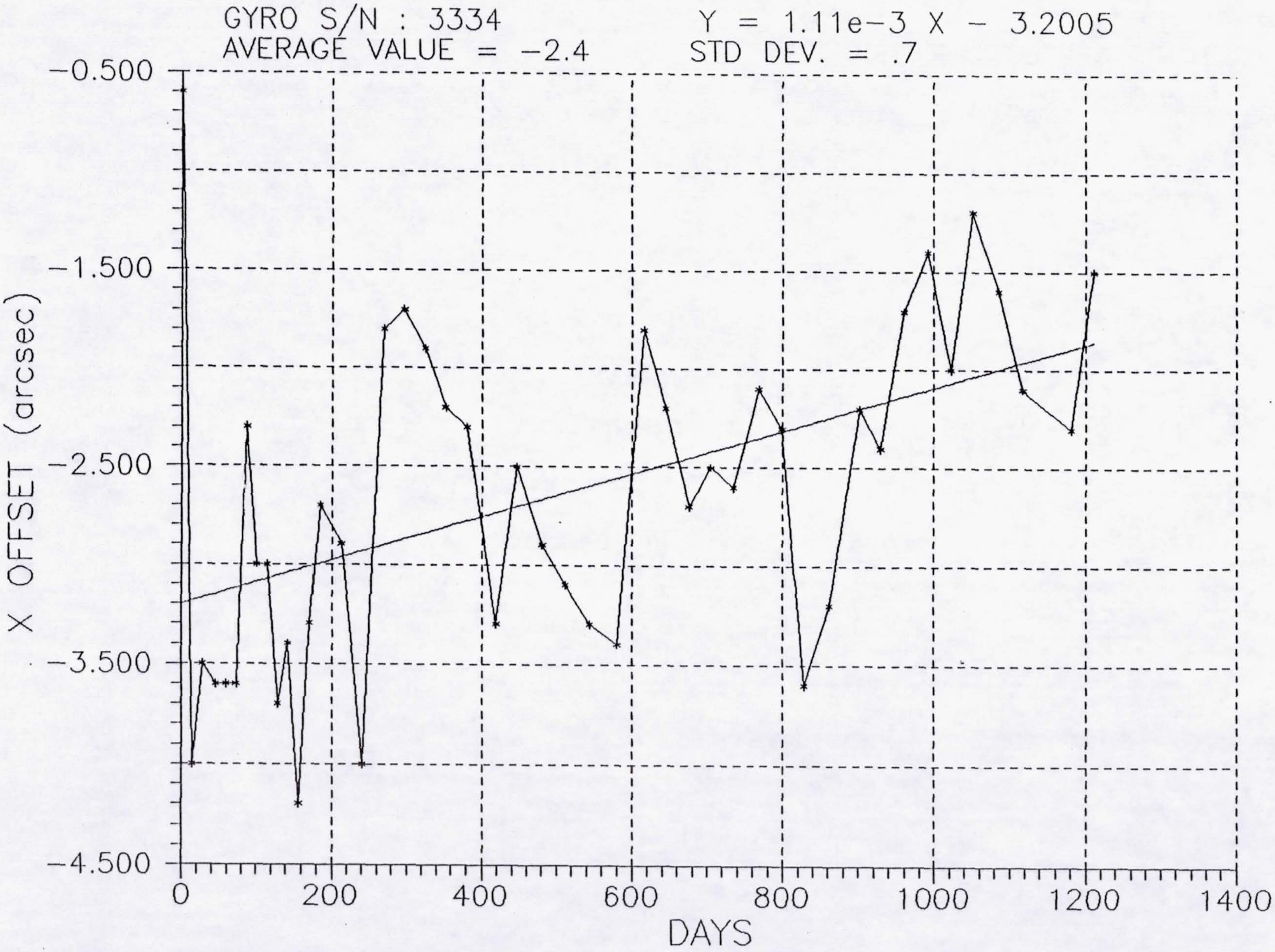
GYRO S/N : 3334
Y = 1.433e-3 X + 32.4965
AVERAGE VALUE = 33.71
STD DEV. = 1.3
MTR RUN CURRENT (mA)
40.000
38.000
36.000
34.000
32.000
30.000
0
200
400
600
800
1000
1200
1400
DAYS

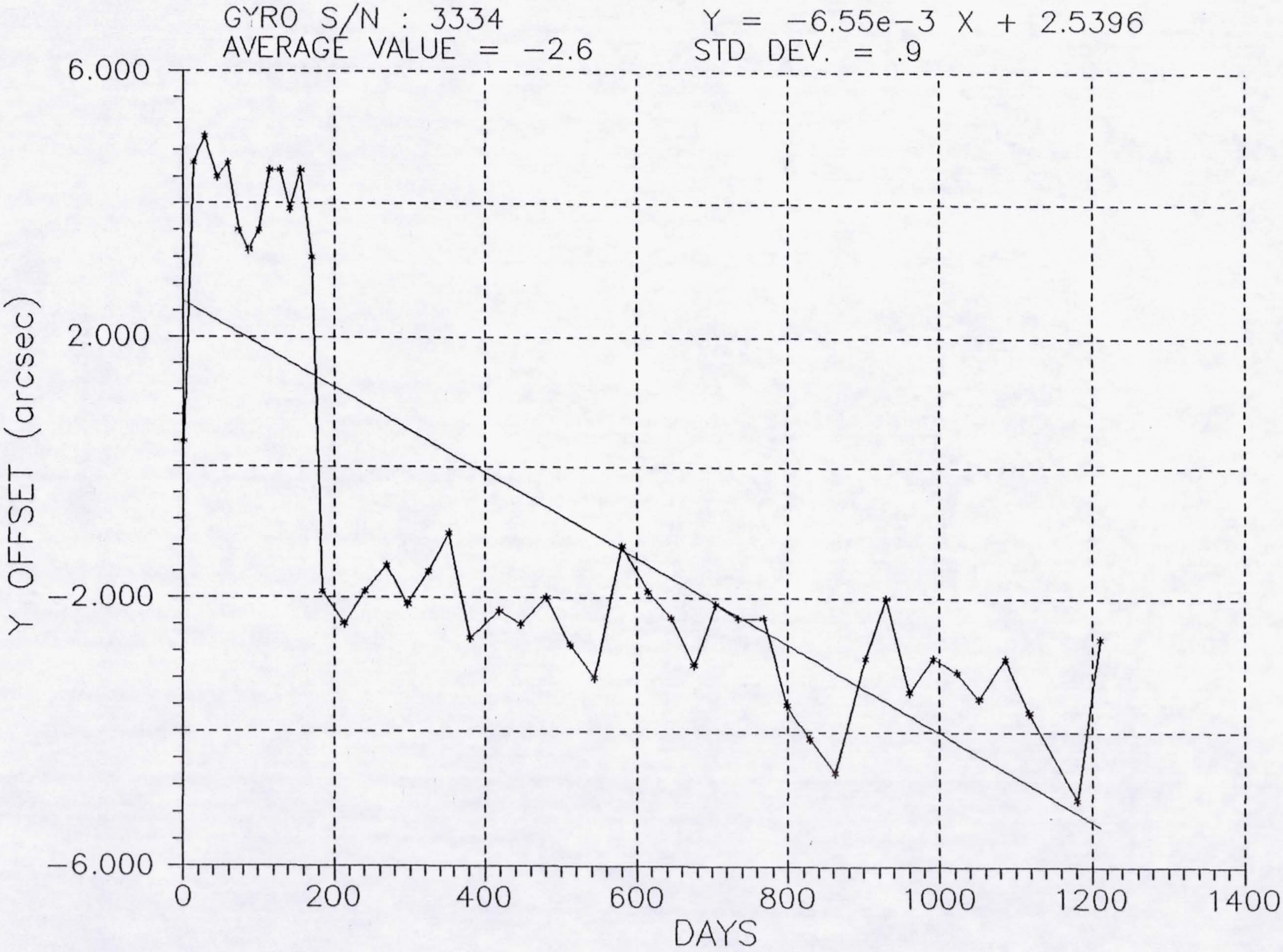

GYRO S/N : 3334
Y = −1.29e−2 X + 79.1648
AVERAGE VALUE = 68.74
STD DEV. = 5.3
110.000
90.000
70.000
50.000
RUN–DN TIME (sec)
0
200
400
600
800
1000
1200
1400
DAYS

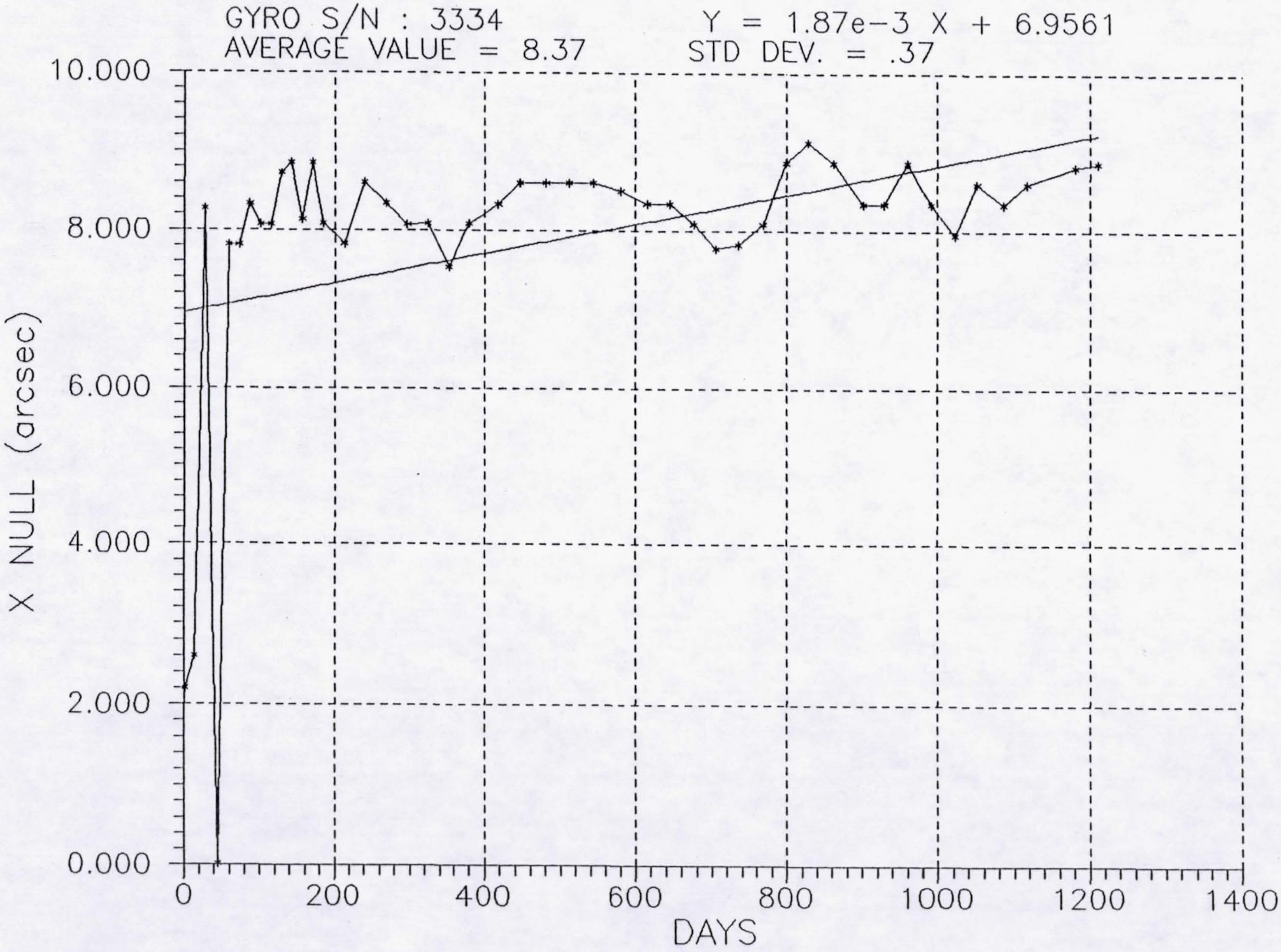

GYRO S/N : 3334
AVERAGE VALUE = 396.9
Y = −3.45e−4 X + 397.1736
STD DEV. = .1
397.300
397.100
396.900
396.700
SAH TUNE FREQ. (Hz)
0
200
400
600
800
1000
1200
1400
DAYS


GYRO S/N : 3334
Y = −3.41e−4 X + 394.5849
AVERAGE VALUE = 394.4
STD DEV. = .1
SAV TUNE FREQ. (Hz)
394.700
394.600
394.500
394.400
394.300
394.200
394.100
0
200
400
600
800
1000
1200
1400
DAYS


GYRO S/N : 3334
AVERAGE VALUE = 18.6
Y = -3.65e-4 X + 18.8664
STD DEV. = .4
TIME CONSTANT (sec)
19.750
19.250
18.750
18.250
17.750
17.250
0
200
400
600
800
1000
1200
1400
DAYS


GYRO S/N : 3334
AVERAGE VALUE = −2.4
Y = 1.11e−3 X − 3.2005
STD DEV. = .7
X OFFSET (arcsec)
−0.500
−1.500
−2.500
−3.500
−4.500
0
200
400
600
800
1000
1200
1400
DAYS


GYRO S/N : 3334
AVERAGE VALUE = −2.6
Y = −6.55e−3 X + 2.5396
STD DEV. = .9
Y OFFSET (arcsec)
6.000
2.000
−2.000
−6.000
0
200
400
600
800
1000
1200
1400
DAYS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400
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800
1000
1200
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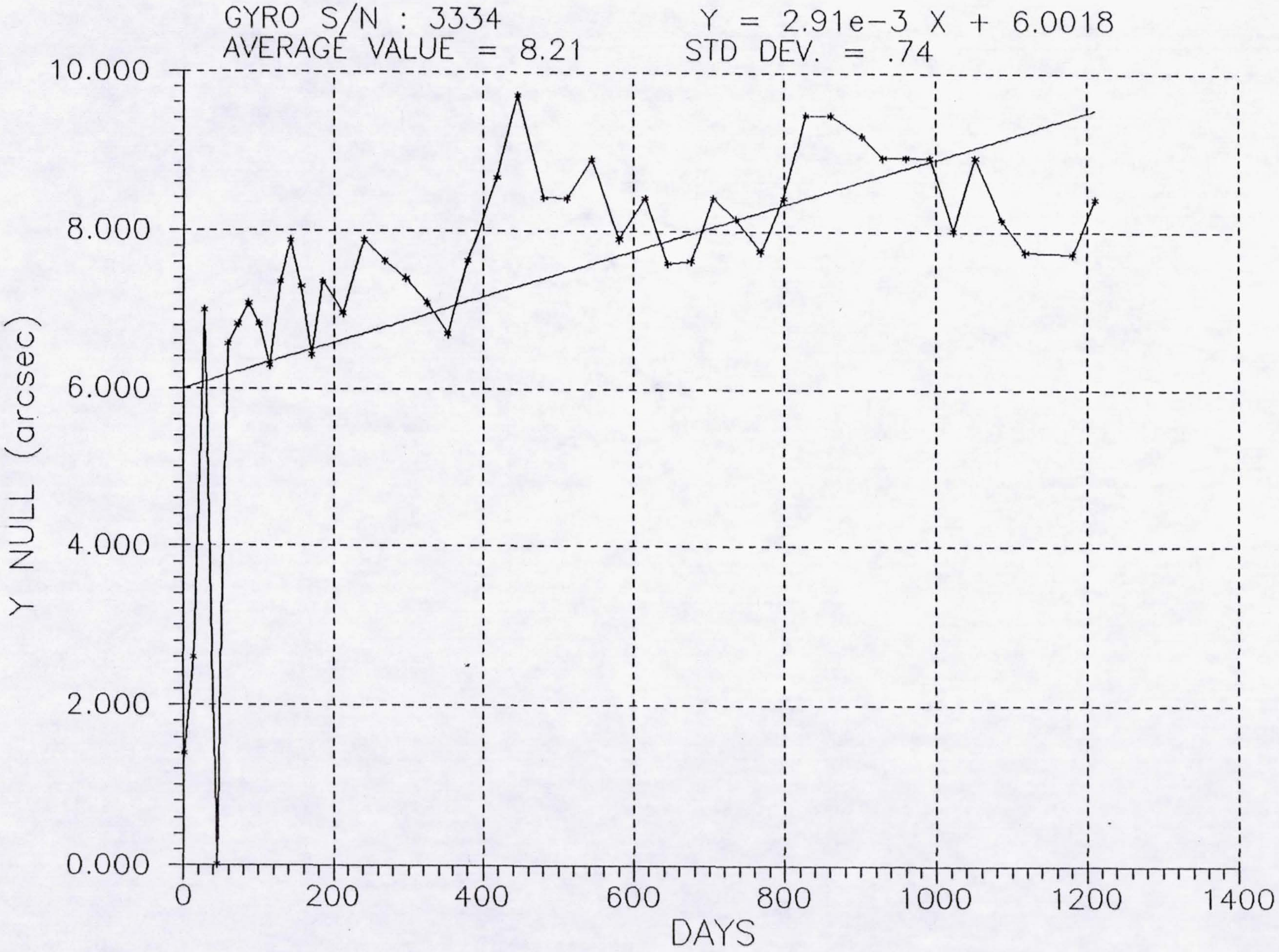
DAYS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800
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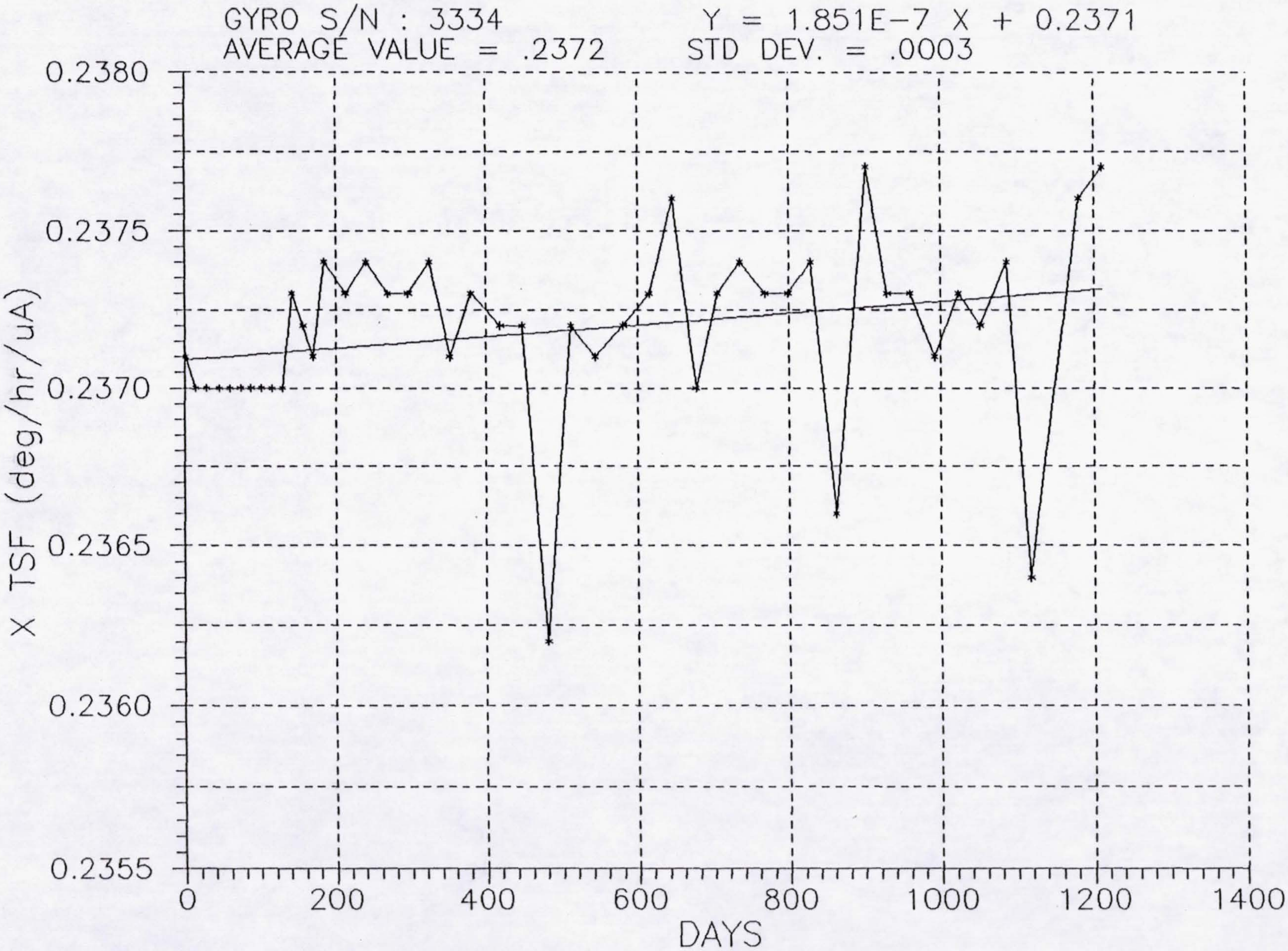
DAYS



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0.2375
0.2370
0.2365
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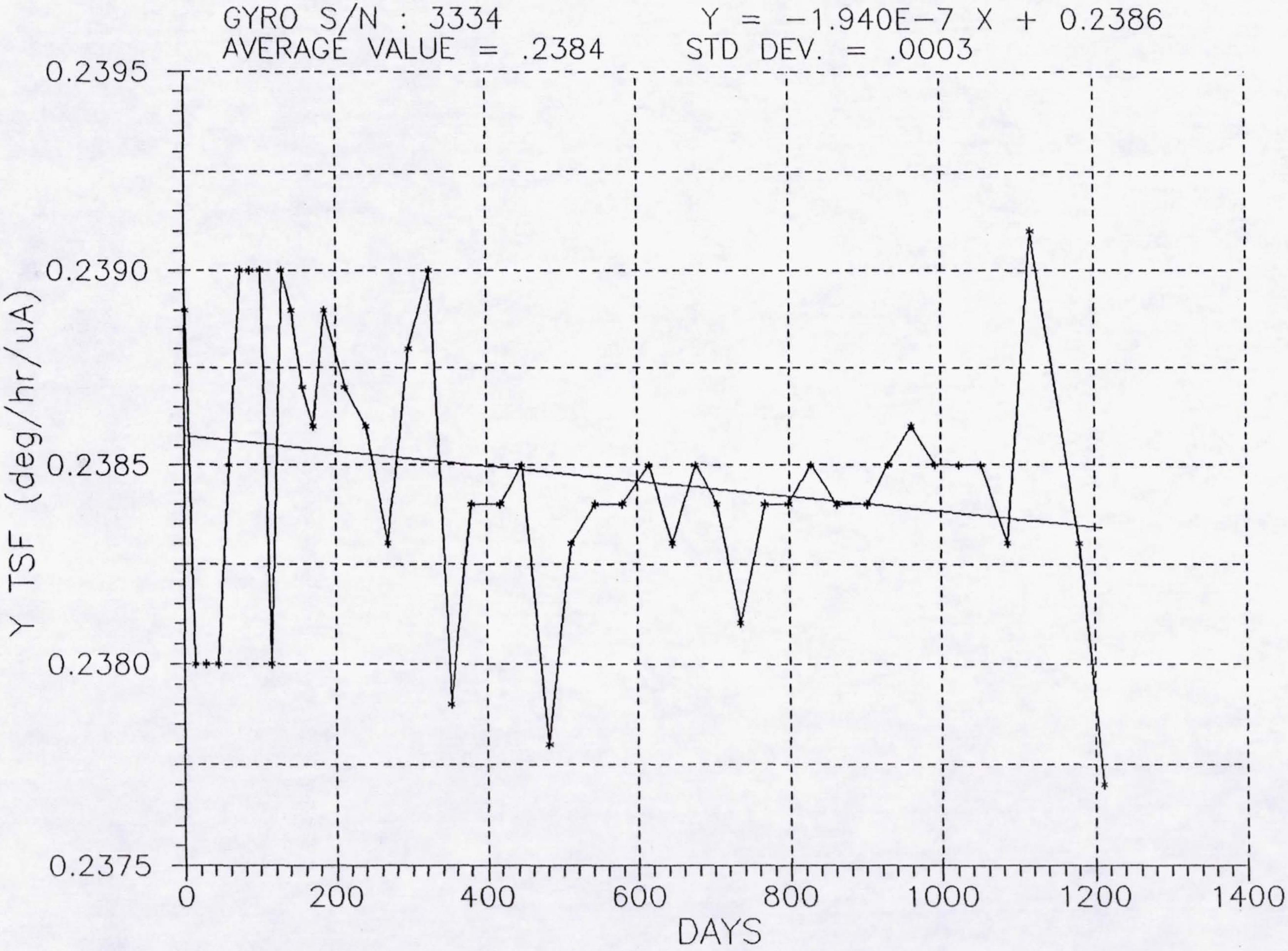
200
400
600
800
1000
1200
1400
DAYS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400
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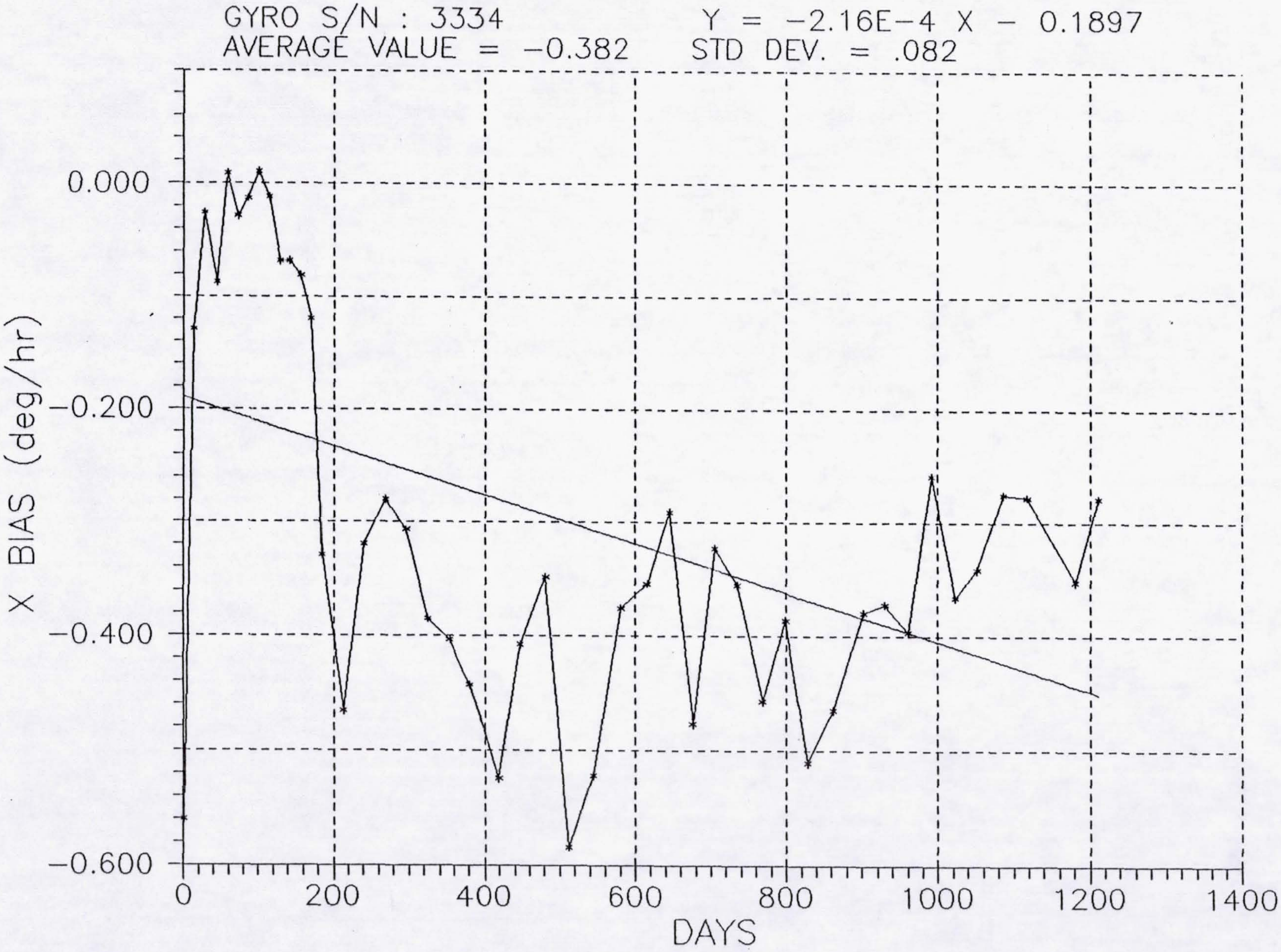
800
1000
1200
1400
DAYS



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800
1000
1200
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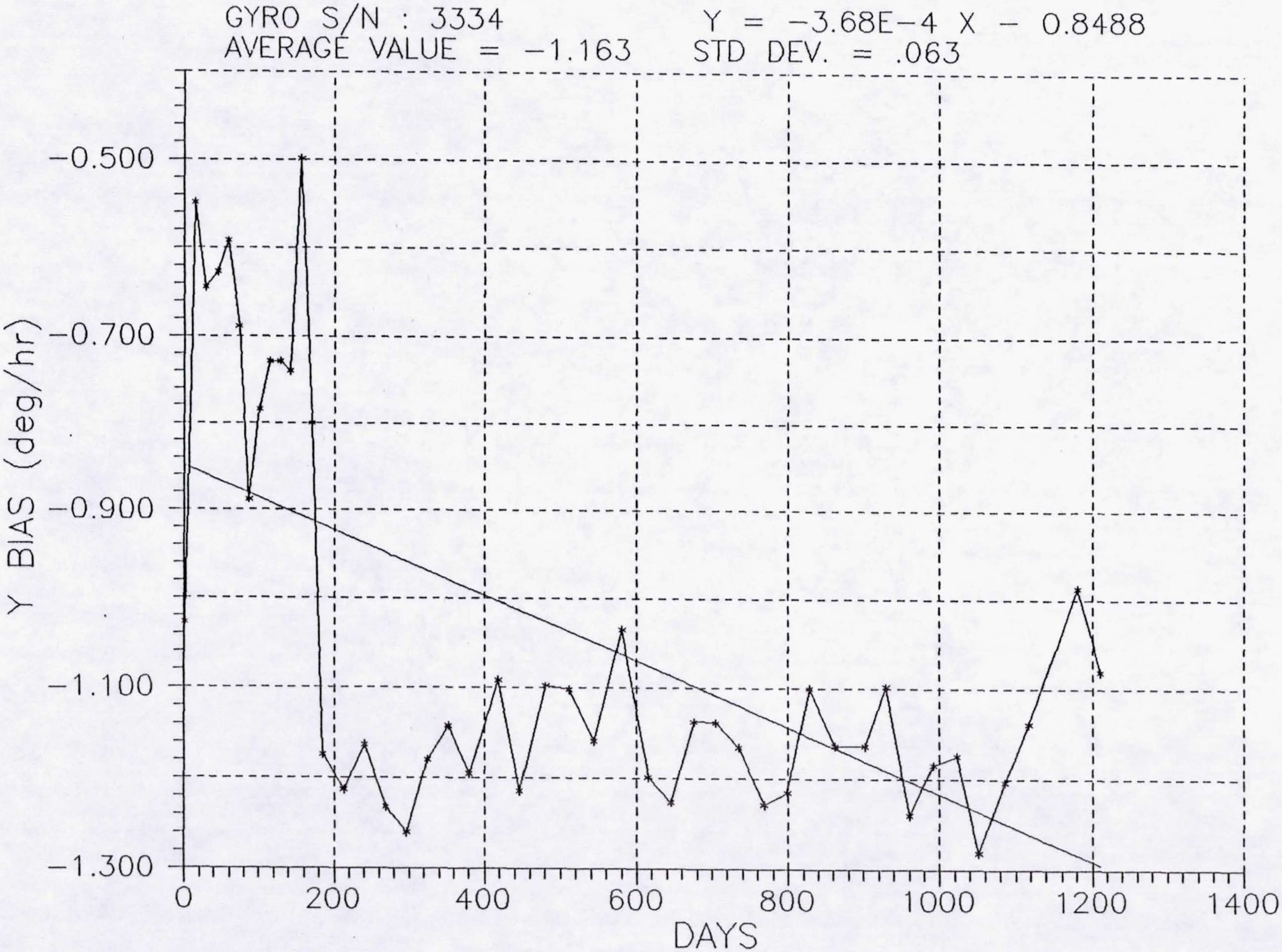
DAYS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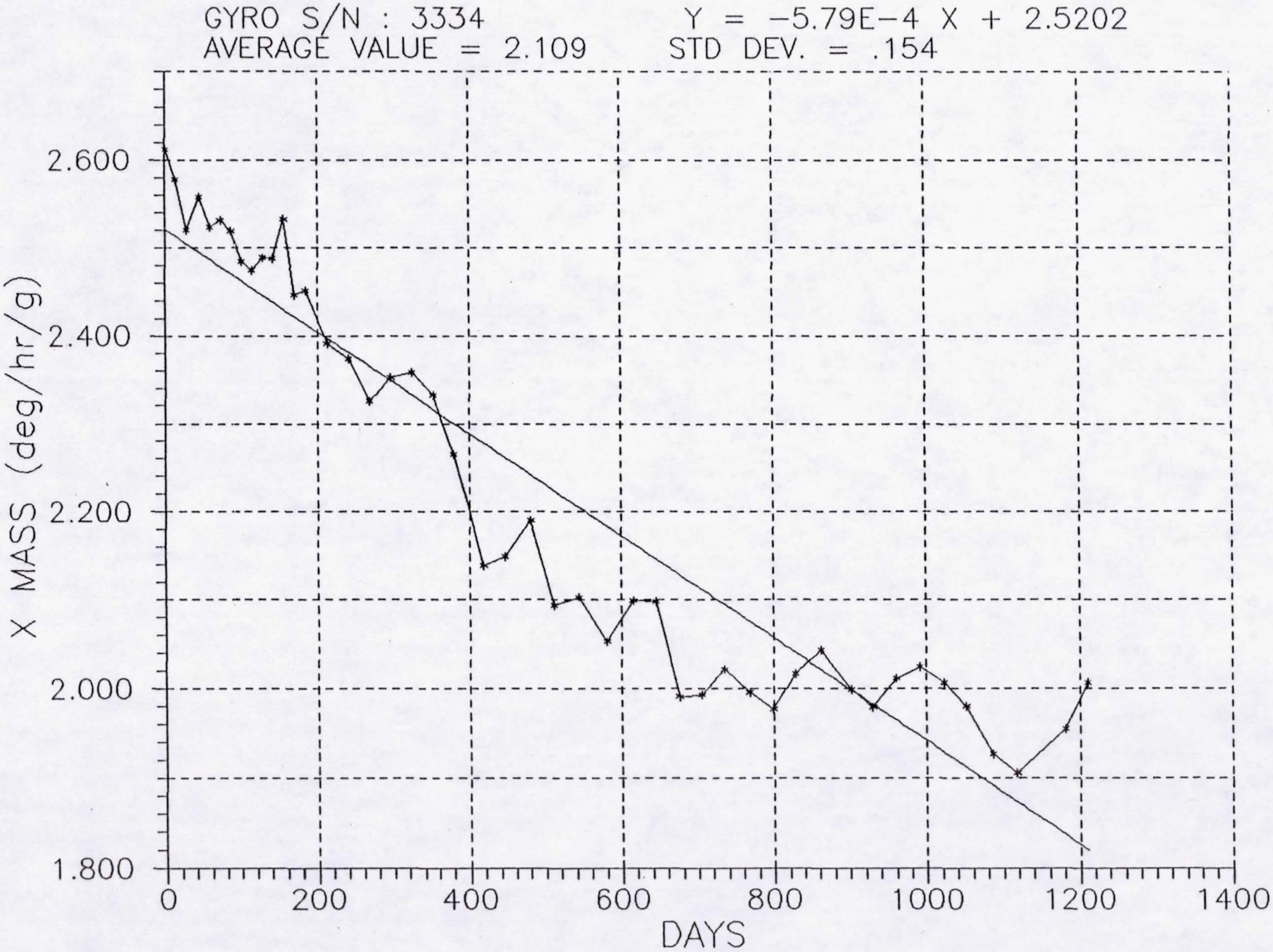
DAYS



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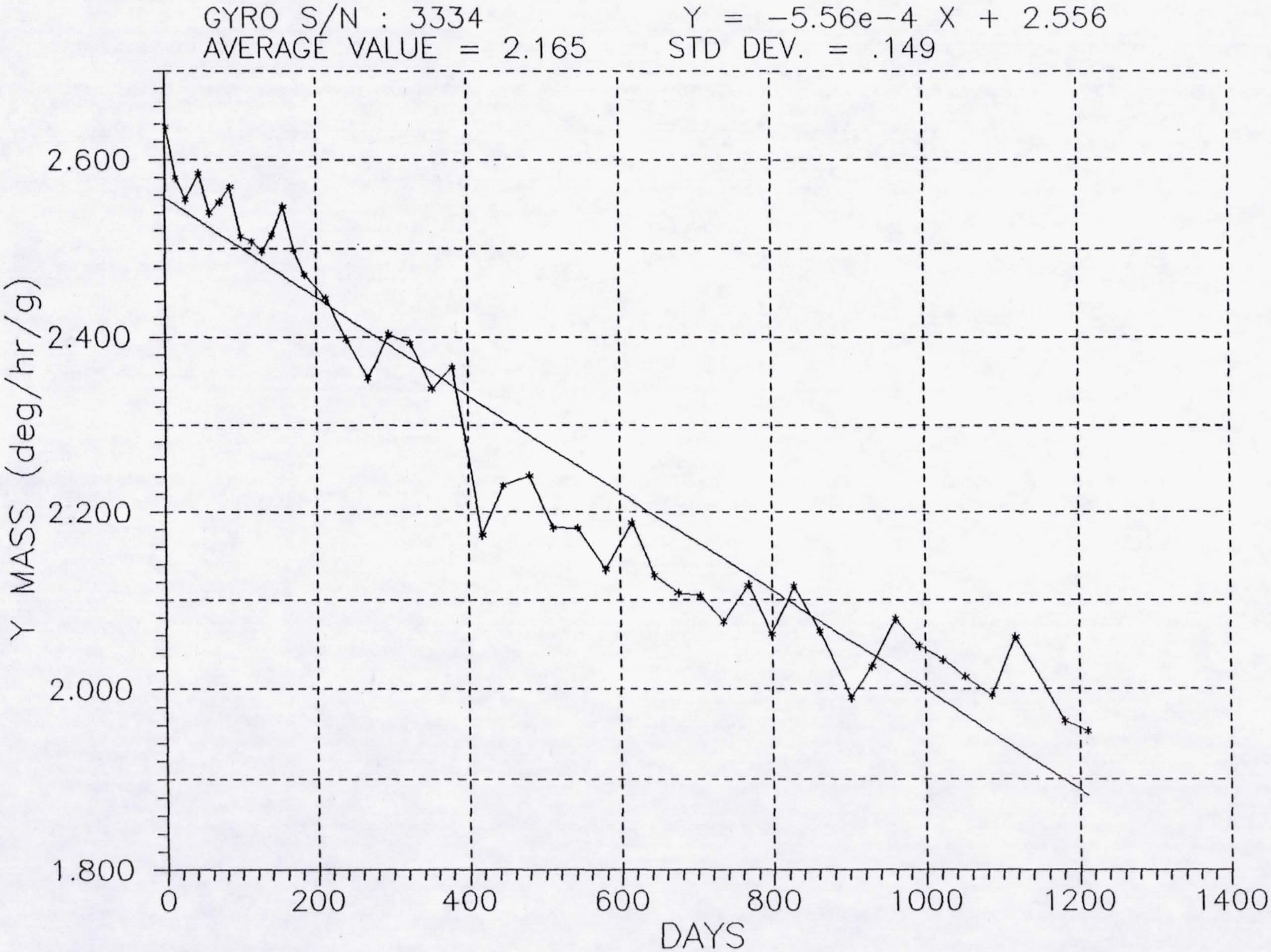
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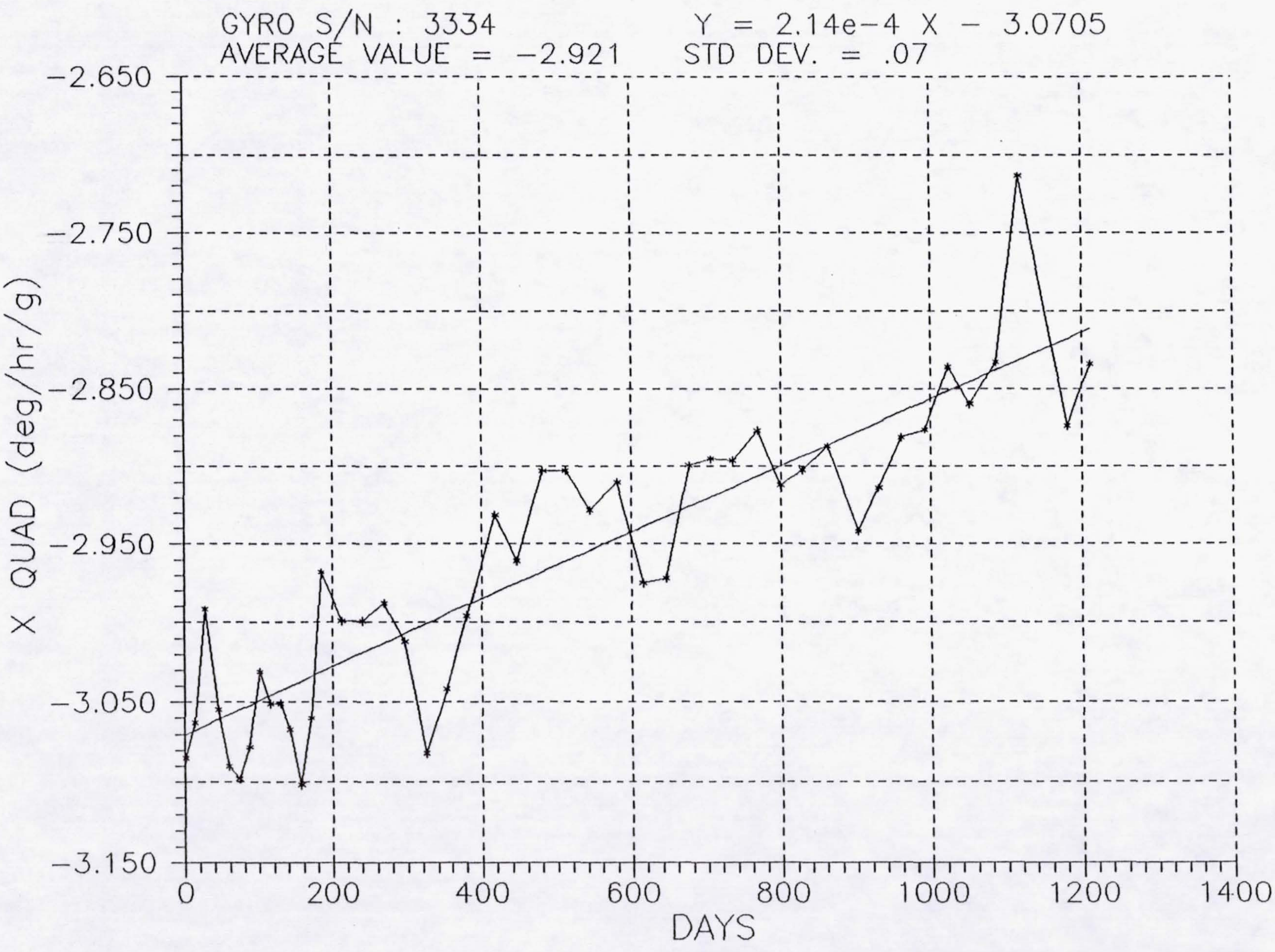
DAYS



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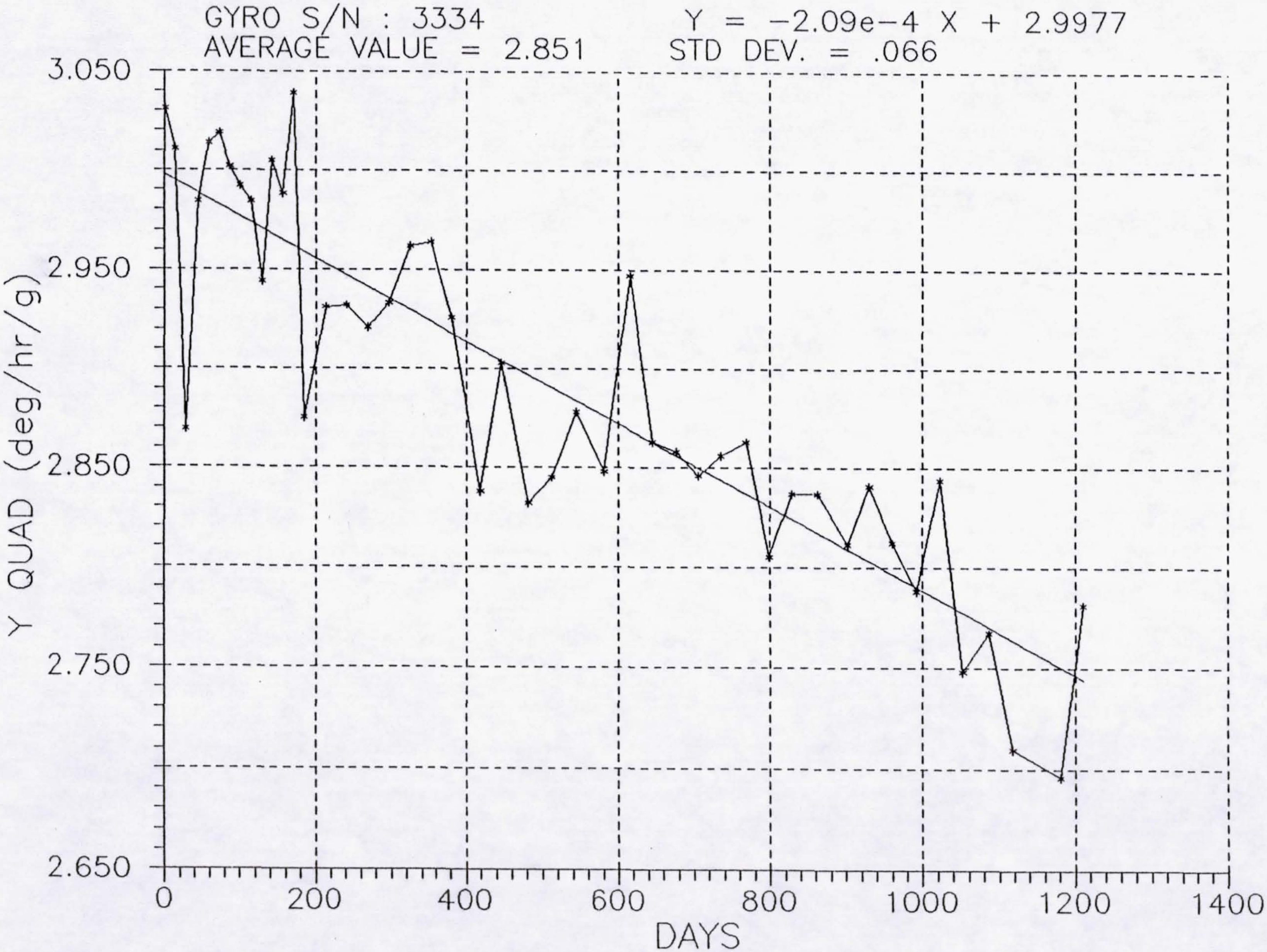
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Y QUAD (deg/hr/g)
0
200
400
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800
1000
1200
1400
DAYS

SECTION 5

APPENDICES

Sheet	Rev	Description	Date	Approved
	A	Released	9-2-92	CBH
	B	Revised per ECN 998	10-6-92	CBH

Test Plan No. 600218

NASA MOD III-T Gyro Life Test Plan

PRODUCTION RELEASE

FEB 17 1993

Compiled Gina M. Elberry	Date 9/02/92	Title
Check	Date 9/2/92	NASA MOD III-T Gyro Life Test Plan
	Date 9/02/92	

Textron Defense Systems 201 Lowell Street Wilmington, MA 01887	Number 600218	Rev B
	Sheet 1 of 9	

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1.0 SCOPE

This plan establishes the tests which are to be performed on the MOD III-T Gyroscope. These tests are divided into two groups: Operating Tests (OT) and Performance Tests (PT). The purpose of this testing is to establish that the MOD III-T Gyroscope (P/N 760900-533) will meet the requirements of a three year space mission. Since the goal of these tests is to establish the performance of these gyros over as many operating hours as possible during this three year period, the tests will not be interrupted unless there is a catastrophic failure or specific direction to do so from the NASA GSFC Technical Officer after consultations with Textron Defense Systems' (TDS) Navigation and Control Test Engineering personnel.

2.0 TEST EQUIPMENT

The test equipment used during the Operating Life Tests and Performance Tests are listed in Sections 2.1 and 2.2.

The commercial equipment power supplies, oscilloscopes, wave analyzer, etc. need not be limited to the models shown but may by replaced by other commercial equipment deemed applicable by TDS' Navigation and Control Test Engineering personnel.

2.1 Operating Test (OT)

Qty.	Description	Part/Model No.
2	Incoflex (TM) Chassis	763828
		(Schematic P/N 761519)
2	Clock, No-Go (48 Khz) Board	767150
		(Schematic P/N 766979)
2	2 Phase Spin Supply Board	(Schematic P/N 763839)
2	Pick-off Supply Board	767152
		(Schematic P/N 764188)
2	Caging Gyro Incoflex	767151
		(Schematic P/N 766828)
2	Fixture	766996
2	Assembly, Preamp/Cable	767038
1	Oven (Dispatch)	LEB-1-28
1	Fluke Thermometer	2176A

1	Fluke Multimeter	8840A
2	+15, -15, +5 Vdc Supply (Power One)	HBAA-40W
2	28 Vdc Supply (Power One)	HC28-2.0
2	Dual DC Power Supply (H/P)	6205b
1	Oscilloscope (Leader)	LBO-520A

2.2 Performance Test (PT)

Qty.	Description	Part/Model No.
1	Incoflex (TM) Chassis	767154 (Schematic P/N 767153)
1	Clock, No-Go (48 Khz) Board	767150 (Schematic P/N 766979)
1	2 Phase Spin Supply Board	(Schematic P/N 763839)
1	Pick-off Supply Board	767156 (Schematic P/N 767157)
1	Caging Gyro Incoflex	767151 (Schematic P/N 766828)
1	Test Cube	767037 (NASA Owned)
1	Assembly, Preamp/Cable	767038 (NASA Owned)
1	+15, -15, +5 Vdc Supply (Power One)	HBAA-40W
1	28 Vdc Supply (Power One)	HC28-2.0
1	Dual DC Power Supply (H/P)	6205b
1	Oscilloscope (Tektronix)	2213
1	Wave Analyzer (H/P)	3581A
1	Computer (H/P)	85
1	(H/P) GP-IO Interface	82940A
1	(H/P) HP-IB Interface	82937A
1	ROM Drawer	82936A
1	16K Memory Module	82903A
1	Printer (H/P)	82905B
1	A/D to Incoflex Chassis Interface Cable	764299
1	Software, Data Cartridge	767160
1	Temperature Controller (Incosym)	TC100A
1	Digital Interface	763285
1	Fluke Multimeter	77
1	Fluke Multimeter	8840A

3.0 TEST PROCEDURE

3.1 Operating Test (OT)

Two gyros will continuously operate for a period of 3 years with periodic interruptions for Performance Tests. At the start of each OT segment, an excitation of

approximately 36 Vrms square wave, shall be applied to saturate the spin motor hysteresis ring; the excitation will then be reduced to a minimum of 16 Vrms or 2 Vrms above the minimum required voltage to keep the gyro operating at synchronous spin speed, whichever is the greater of the two. The operating minimum voltage will be determined prior to the start of the OT and will remain the same throughout the life of the OT. The gyros shall operate in a torque rebalance loop while at synchronous spin speed. Each gyro will be mounted onto a fixture (P/N 766996) and placed within the temperature controlled oven which is maintained within a range of 125 to 180°F per the block diagram. Periodically, both gyros will be removed from the oven and undergo performance tests at a specified temperature. Prior to shutdown and removal, the synchronous spin speed shall be verified and recorded in the Operating Test Bed (OTB) Log.

Following each PT period, the gyros will be remounted to the fixture (P/N 766996) and returned to the oven. Upon each return to the oven, the gyros will be oriented to a new position. This is to allow the migration of the bearing lubricant to be more evenly distributed in the earth's gravitational field. The order of the orientations is to be as follows: 1) Spin axis vertical, Z-up; 2) spin axis horizontal, X-up; 3) spin axis vertical, Z-down; and 4) spin axis horizontal, Y-up. All gyro removals, remounts and orientation will be recorded on the OTB Log. The gyro test position sequence and time duration is listed in Table 1.

Table 1
Orientation of Gyro During Life Test

Test	Position	Time	Test	Position	Time
44 01	SAV-Z Up	2 Wks	23	SAV-Z Down	1 Mo
45 02	SAH-X Up	2 Wks	24	SAH-Y Up	1 Mo
46 03	SAV-Z Down	2 Wks	25	SAV-Z Up	1 Mo
47 04	SAH-Y Up	2 Wks	26	SAH-X Up	1 Mo
05	SAV-Z Up	2 Wks	27	SAV-Z Down	1 Mo
06	SAH-X Up	2 Wks	28	SAH-Y Up	1 Mo
07	SAV-Z Down	2 Wks	29	SAV-Z Up	1 Mo
08	SAH-Y Up	2 Wks	30	SAH-X Up	1 Mo
09	SAV-Z Up	2 Wks	31	SAV-Z Down	1 Mo
10	SAH-X Up	2 Wks	32	SAH-Y Up	1 Mo
11	SAV-Z Down	2 Wks	33	SAV-Z Up	1 Mo
12	SAH-Y Up	2 Wks	34	SAH-X Up	1 Mo
13	SAV-Z Up	2 Wks	35	SAV-Z Down	1 Mo
14	SAH-X Up	1 Mo	36	SAH-Y Up	1 Mo
15	SAV-Z Down	1 Mo	37	SAV-Z Up	1 Mo
16	SAH-Y Up	1 Mo	38	SAH-X Up	1 Mo
17	SAV-Z Up	1 Mo	39	SAV-Z Down	1 Mo
18	SAH-X Up	1 Mo	40	SAH-Y Up	1 Mo
19	SAV-Z Down	1 Mo	41	SAV-Z Up	1 Mo
20	SAH-Y Up	1 Mo	42	~~SAV-X Up~~ SAH, X+	1 Mo
21	SAV-Z Up	1 Mo	43	~~SAH-Z Down~~ SAV, Z+ SAV	1 Mo ?
22	SAH-X Up	1 Mo			

Where SAV - Spin Axis Vertical
SAH - Spin Axis Horizontal
Z-Axis - Aligned with Spin Axis

3.2 Performance Test (PT)

During the first 6 months, every 2 weeks each gyro will be transferred to the MOD-III-T Performance Test Procedure (PTP) Test Stand for Performance Testing. After 6 months of operation has elapsed, the PT interval shall change to once per month. The spin motor power will be set at approximately 26 Vrms throughout all performance testing. The PT temperature will be 70 ± 2°C. The temperature will be recorded on the PT Data Sheet.

All PT results will be recorded on the PT Data Sheet. A listing of the PTs to be completed are as follows:

3.2.1 Rotor Synchronous Run-up Time

The time to reach synchronous spin speed.

3.2.2 Motor Start Current

Peak start current at 26 Vrms.

3.2.3 Motor Run Current

The steady state operating current at 26 Vrms.

3.2.4 Rotor Run Down Time

3.2.5 Spin Axis Horizontal Tuned Frequency

3.2.6 Spin Axis Vertical Tuned Frequency

3.2.7 Rotor Damping Time Constant

3.2.8 X & Y Pick-off Offsets

3.2.9 X & Y Pick-off Null Quadrature

3.2.10 8 Position Test Measuring

3.2.10.1 X & Y Torquer Scale Factors

3.2.10.2 X & Y G-Insensitive Drift (Bias)

3.2.10.3 G-Sensitive Drift (Direct Mass Unbalance)

3.2.10.4 G-Sensitive Drift (Quadrature Mass Unbalance)

4.0 QUALITY ASSURANCE REQUIREMENTS

4.1.1 Operating Test Bed (OTB)

The gyros will be installed in the OTB as shown in the Block Diagram, Drawing No. 767159.

4.1.2 Performance Test Procedure (PTP) Test Stand

The MOD III PTP Test Stand is the standard BIT Stand modified to perform the Run Down Test, Block Diagram, Drawing No. 767158. The part number for the modified Test Stand is 767154. The Pick-off Supply Card also required a modification to perform the Run Down Test. The drawing number for the modified Card is 767156.

4.2 The Operational/Test Log

The NASA MOD III-T Life Test Log Document No. 910257 will contain:

a) Life Test History

- Gyro orientation, date and time for start and stop of each segment.
- Verification of the gyro in sync status at the start and stop of each segment.

b) Tabulation of gyro performance data for each test performed at the PTP station.

c) Tabulation of equipment used in the Life Test Bed. To include calibration dates and calibration due dates where required, along with dates for exchanges of equipment where required.

d) Tabulation of equipment used in the Performance Test station along with calibration information where required.

The Appendix contains the Test Log No. 910257.

4.3 Gyro Operation Verification

1) Assemble the system as shown in Block Diagram 610886.

2) Spin Pick-off monitored on Channel A of the oscilloscope.

3) Phase A of the spin excitation monitored on channel B of the oscilloscope.

4) Oscilloscope internally synced from channel A.

If the gyro is in sync, the spin pick-off and the spin excitation frequencies will be locked to each other as observed on the oscilloscope.

If the gyro is not in sync, the spin pick-off and excitation signals will be moving with respect to each other when observed on the oscilloscope.

A Quality Assurance (QA) person shall witness that the gyro is in sync at the start and completion of each segment of the Life Test. A statement of these certifications shall be entered in the log by the witnessing QA person and stamped off.

4.4 Test Data Verification

All PT test data shall be witnessed by a QA person who shall apply an appropriate stamp to the data sheet entries. This data shall be maintained in the test log.

4.5 Metrology

Quality Assurance shall ensure that all test equipment are maintained within the requirements established by TDS' Navigation and Control Group.

Any time an item of test equipment is replaced, the fact shall be noted in the log along with the new item's nomenclature, model, serial number and next recalibration required date stamped off by QA.

4.6 Failed Test Equipment

Any time an item of test equipment fails, it will be noted in the log with a statement as to the failure mode, if available. The new item of test equipment's

nenclature, model, serial number and next recalibration required date stamped off by QA.

4.7 Go, No-Go and Pass Fail Criteria

Results of the first month of testing will be reviewed jointly by TDS' Navigation and Control Test Engineering and the NASA GSFC Technical Officer. The nominal performance for the Operational and Performance Tests will be established by this review. These nominal performance limits will be entered into the log book and signed off by QA. If the gyro test data exceeds these nominal performance limits, the NASA GSFC Technical Officer must be notified. The Life Test will continue until a joint decision is made by TDS' Navigation and Control Test Engineering and the NASA GSFC Technical Officer to interrupt or discontinue the Life Test program. Similarly, if the gyro fails to operate or is deemed unacceptable, TDS shall notify the NASA GSFC Technical Officer before investigating the failure mode and estimating the cost of repair.

MOD III-T NASA Life Test
Performance Test (PT) Data Sheet

Gyro Serial No.: Date:

Test No.: After Test Sequence No.:

Paragraph	Parameter	Units	Nominal Performance	Measurement
3.2.1	Run-up Time	Secs	< 16	
3.2.2	Motor Start Current	Milli-Amps	TBD	
3.2.3	Motor Run Current	Milli-Amps	< 600	
3.2.4	Motor Run Down Time	Secs	TBD	
3.2.5	SAH Tuned Frequency	Hertz	397-403	
3.2.6	SAV Tuned Frequency	Hertz	393-401	
3.2.7	Rotor Damping Time Constant	Secs	> 15	
3.2.8 (A)	Offset X-Axis	Arc-Secs	±6	
3.2.8 (B)	Offset Y-Axis	Arc-Secs	±6	
3.2.9 (A)	X-Null Quadrature	Arc-Secs	±20	
3.2.9 (B)	Y-Null Quadrature	Arc-Secs	±20	
3.2.10.1 (A)	X-Torquer Scale Factor	Deg/Sec/Ma	≥ 0.22	
3.2.10.1 (B)	Y-Torquer Scale Factor	Deg/Sec/Ma	≥ 0.22	
3.2.10.2 (A)	X-Axis Bias	Deg/Hr	±20	
3.2.10.2 (B)	Y-Axis Bias	Deg/Hr	±20	
3.2.10.3 (A)	X-Axis Direct Mass Unbalance	Deg/Hr	±10	
3.2.10.3 (B)	Y-Axis Direct Mass Unbalance	Deg/Hr	±10	
3.2.10.4 (A)	X-Axis Quad Mass Unbalance	Deg/Hr	±10	
3.2.10.4 (B)	Y-Axis Quad Mass Unbalance	Deg/Hr	±10	

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	Sheet 3 of 5	

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MOD III-T Gyro

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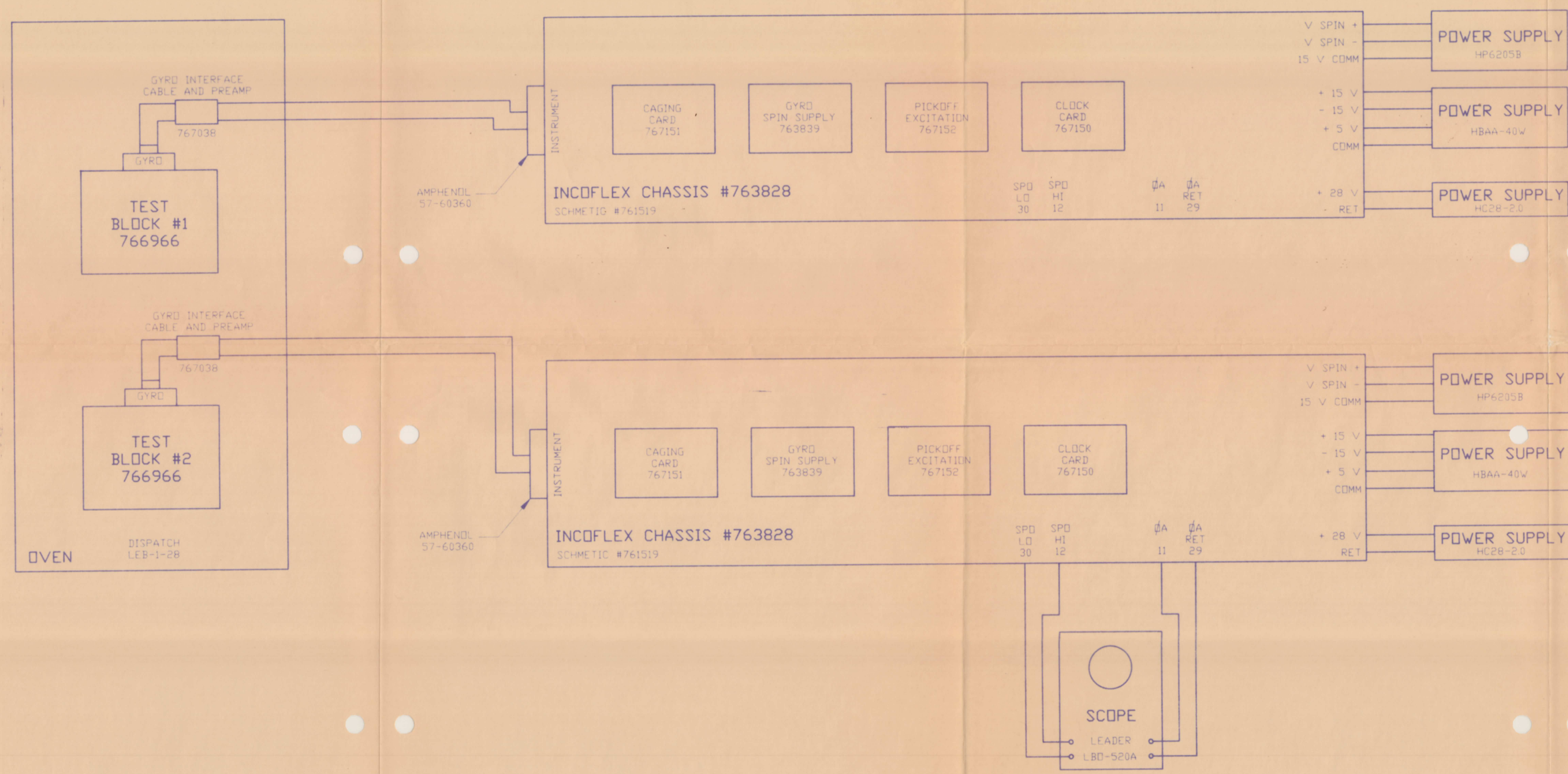

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NASA MOD IIIT
OPERATIONAL LIFE TEST BED
BLOCK DIAGRAM

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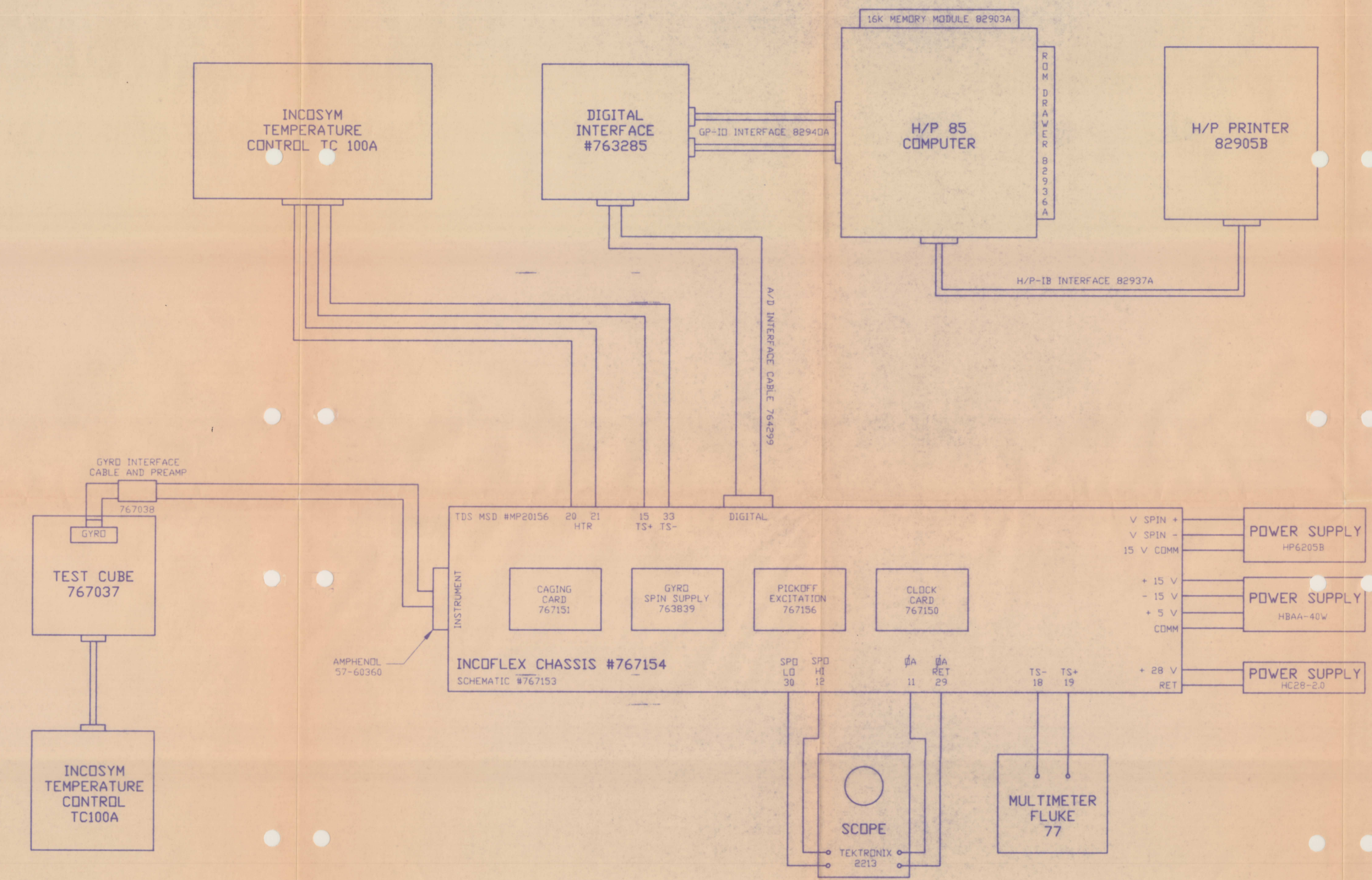

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